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NACA TN 2352

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SPIN-TUNNEL INVESTIGATION OF THE EFFECTS OF MASS AND DIMENSIONAL VARIATIONS ON THE SPINNING CHARACTERISTICS OF A LOW-WING SINGLE-VERTICAL-TAIL MODEL TYPICAL OF PERSONAL-OWNER AIRPLANES

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Washington
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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the effects of mass and dimensional variations on the spin and recovery characteristics of a model representative of present-day four-place personal-owner airplane designs. The results of the investigation are also analyzed in light of requirements for personal-owner airplanes as set forth in Civil Air Regulations Part 3 as amended to November 1, 1949.

The investigation showed that for personal-owner, or liaison, airplanes, satisfactory recovery characteristics can be readily obtained even if the tail-damping power factor is not very great, provided the recovery technique used is full rapid rudder reversal followed approximately 1/2 turn later by forward movement of the stick. Other recovery techniques, however, such as premature movement of the stick forward before the rudder is reversed may lead to slow recoveries for the loading condition having mass extended along the fuselage and retracted along the wings in combination with low values of tail-damping power factor. Also, the results indicated that for recovery by merely neutralizing both controls, especially for rearward center-of-gravity positions, high values of tail-damping power factor may have an adverse effect upon recoveries. Mass changes generally had an appreciable effect on the model spin and recovery characteristics for low values of the tail-damping power factor but had little effect on the model spin and recovery characteristics for high values of the tail-damping power factor. Changes in tail-damping power factor also had an appreciable effect on the spin-recovery characteristics for the loading condition having the mass extended along the fuselage and retracted along the wings; whereas, when mass was extended along the wings and retracted along the fuselage, changes in tail-damping power factor had only little effect. Changing the vertical- or horizontal-tail design generally had little effect on the spin-recovery characteristics except for the loading condition having mass extended along the fuselage and retracted along

the wings in combination with low values of the tail-damping power factor. Different wing plan forms had little effect on the model spin and recovery characteristics.

The results of the investigation indicated that unless the rudder can be designed to float against the spin, recovery from a spin by releasing controls as is stipulated in Civil Air Regulations Part 3 as amended to November 1, 1949 might be difficult unless the elevator can be made to float at deflections farther down than neutral. The investigation indicated that the other requirements for spin recovery by various movements of the controls as specified in the aforementioned regulations could probably be met for the various model configurations and mass distributions investigated by maintaining the center of gravity at a forward position and utilizing a high tail-damping power factor.

INTRODUCTION

The investigation reported herein is part of a general investigation being conducted in the Langley 20-foot free-spinning tunnel to provide design information for proportioning personal-owner or liaison airplanes for satisfactory recovery from spins and for spin-proofing. Reference 1, which presents the results of spin-tunnel tests of a twin-tail model, and reference 2, which presents design charts for proportioning personal-owner airplanes for satisfactory spin recovery, are previous parts of the investigation. This paper presents the results of an investigation conducted on a low-wing single-vertical-tail model typical of present-day four-place personal-owner airplane designs. The investigation was conducted to provide airplane designers with spin and recovery data for a variety of design configurations. The results of the investigation have also been examined in light of the requirements for personal-owner airplanes set forth in Civil Air Regulations Part 3 as amended to November 1, 1949 (reference 3).

The model was investigated at two distributions of mass corresponding to the approximate extremes in loadings that exist for current single-engine personal-owner airplanes and at two center-of-gravity positions (25 and 40 percent of the mean aerodynamic chord). Five basic-tail configurations were investigated (each of the tail arrangements having various vertical locations of the horizontal tail). Most of the investigation was conducted with a round-tip rectangular wing installed on the model, but the effects of installing square tips on the rectangular wing and the effects of installing a round- or a square-tip tapered wing were also determined. Although no tests were conducted by releasing controls as is stipulated in reference 3, sufficient tests were conducted by movement of the controls to specific settings so that the recovery characteristics by releasing controls may be estimated, provided the floating tendencies of the controls are known.

SYMBOLS

b	wing span, feet
S	wing area, square feet
$\bar{c}$	mean aerodynamic chord, feet
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below fuselage reference line)
m	mass of airplane, slugs
X,Y,Z	longitudinal, lateral, and vertical body axes, respectively (see fig. 1)
I_X,I_Y,I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-feet^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slugs per cubic foot
μ	relative density of airplane $(m/\rho Sb)$
α	angle between thrust line and vertical (approx. equal to absolute value of angle of attack at plane of symmetry), degrees
ϕ	angle between span axis and horizontal, degrees
V	full-scale true rate of descent, feet per second
Ω	full-scale angular velocity about spin axis, revolutions per second

M aerodynamic pitching moment, foot-pounds

δ_e elevator deflection, degrees

δ_r rudder deflection, degrees

δ_a aileron deflection, degrees

TDPF tail-damping power factor (see reference 2)

APPARATUS AND METHODS

Model

The model was constructed principally of balsa and was reinforced with spruce and cedar. The wing and tail units were independently removable and interchangeable to permit the testing of any configuration. A three-view drawing of the model in one of its most extensively investigated configurations is shown as figure 1. Drawings of the various wing configurations and the tail configurations investigated are shown as figures 2 to 7, and photographs of the wings and the basic-tail arrangements are shown as figures 8 and 9. The rectangular wing and the wing having a taper ratio of 2:1 were investigated with both round and square tips (see fig. 2). Most of the investigation was conducted with a tail configuration considered to be an average-size tail for a light personal-owner airplane. This combination of an average-size horizontal tail and an average-size vertical tail with full-length rudder (hereinafter referred to as the normal horizontal and vertical tails, respectively) is designated the normal tail (tail 1). The variations from the normal tail investigated are as follows: normal vertical tail replaced by large vertical tail with full-length rudder (tail 2), full-length rudder of normal vertical tail replaced by a partial-length rudder (tail 3), normal horizontal tail replaced by large horizontal tail (tail 4), and normal horizontal tail moved rearward and full-length rudder of normal vertical tail replaced by a partial-length rudder (tail 5).

For each of the five basic tails, the tail-damping power factor was varied by changing the vertical position of the horizontal tail on the vertical tail. The value of the tail-damping power factor for any given tail arrangement is designated by the letters a, b, c, d, e, f, and x for the following tail-damping power factors, respectively: 50×10^{-6}, 100×10^{-6}, 200×10^{-6}, 300×10^{-6}, 600×10^{-6}, 1200×10^{-6}, and 0. For example, tail 1a is the normal tail (normal vertical tail with full-length rudder and normal horizontal tail) with the horizontal tail so positioned vertically that the tail-damping power factor is 50×10^{-6}.

The dimensional characteristics and designations of the various tail configurations investigated are tabulated in table I. The dimensional characteristics of the model in terms of full-scale values with the normal vertical and horizontal tails installed are listed in table II.

The model was proportioned to a size that could be conveniently investigated in the spin tunnel. The scale of the model was considered to be 1/12.4, based on the model size and the average dimensions obtained for a large number of personal-owner airplane designs. The results are given, therefore, in terms of a full-scale airplane on the basis of a $\frac{1}{12.4}$-scale model.

A remote-control mechanism was installed in the model to actuate the movable controls. For recovery tests, sufficient hinge moments were applied to the controls to move them fully and rapidly to the desired positions. The propeller was not simulated on the model because the results of previous tests (data unpublished) have indicated little effect of a windmilling propeller on the spin characteristics of models of conventional airplanes. Landing gear was not installed on the model inasmuch as the data presented in reference 4 indicate that extension of the landing gear had a negligible effect on the spin and recovery characteristics.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 5 for the Langley 15-foot free-spinning tunnel except that the model launching technique has been changed. With the controls set in the desired position, a model is now launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of the remote-control mechanism. After recovery, the model dives into a safety net. The spin data obtained are then converted to corresponding full-scale values by methods also described in reference 5. A photograph of the model used in this investigation spinning in the tunnel is shown as figure 10.

In accordance with standard spin-tunnel procedure, tests were performed to determine the spin and recovery characteristics of the model for the normal spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin) and for various other aileron-elevator combinations including neutral and maximum settings of the control surfaces for the various model loadings and configurations. Recovery was generally attempted by rapid reversal of the rudder from with to against the spin or to neutral. Recoveries were also attempted by moving the elevator or ailerons in conjunction with the rudder.

Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. The criterion for a satisfactory recovery from a spin for a model has been adopted as $2\frac{1}{4}$ turns or less, based primarily on the probable loss of altitude of a corresponding airplane during the recovery and subsequent dive.

For recovery attempts in which the model struck the safety net before recovery could be effected because of the increase in spin radius, because of the wandering nature of the model after the rudder was reversed, or because of an unusually high rate of descent, the number of turns from the time the controls were moved to the time the model struck the safety net was recorded. This number indicated that the model required more turns to recover from the spin than shown, as for example >5. A >2-turn recovery, however, does not necessarily indicate an improvement when compared with a >5-turn recovery. Recovery attempts for those conditions in which the model failed to recover in less than 10 turns is indicated by ∞. In some instances, recovery attempts were made before the model had reached its final steep attitude because the model rate of descent was higher than could be easily controlled in the tunnel. Such recovery data are noted in the charts as "recovery attempted before model reached its final steep attitude." Recovery results so obtained are considered conservative; that is, the recoveries are somewhat slower than those that would have been obtained had the model been in its final steep spin attitude. If the model recovered without control movement when launched in a spinning attitude with the controls set for the spin, the condition was recorded as "no spin."

Model Recovery Requirements

Sufficient tests were conducted to determine whether the various configurations tested would satisfactorily meet established spin-tunnel requirements for satisfactory recovery. One of these requirements is that a model recover within $2\frac{1}{4}$ turns when the control settings are deviated slightly from the normal spinning control configuration and the rudder is not fully reversed. This criterion for recovery has been applied to military airplanes at the Langley 20-foot free-spinning tunnel. For satisfactory recovery by rudder reversal alone for the present model the ailerons were set 1/3 of their full deflection in the direction conducive to slower recoveries, the elevator was set to either 2/3 of its full-up position or to its full-up position (depending on which gave the slower recoveries) and the rudder was reversed from full with to only 2/3 of its full deflection against the spin. In addition, sufficient tests were also conducted to determine whether the model would recover when the ailerons and elevator were deviated from the normal spinning control configuration as just described when both the rudder and elevator were reversed.

It was also desired to compare the results of the tests with the data presented in reference 2, which presents tail-design requirements for satisfactory spin recovery for personal-owner airplanes. In reference 2 the design charts presented for recovery by rudder reversal only were obtained from model spin tests by assuming satisfactory recovery if the model recovered within $2\frac{1}{4}$ turns after rudder reversal from any elevator position with ailerons at neutral. This criterion was used in place of the one mentioned in the previous paragraph because of the then-limited existing data applicable to personal-owner aircraft. At the time of publication of reference 2 it was believed that this criterion was more rigid than the previously noted military-airplane criterion and it was also believed that the tail of a light plane should be sufficiently powerful to terminate the spin by rudder reversal alone without the assistance of the elevator. Reference 2 provides tail-design data for spin recovery for the low range of relative densities common to personal-owner airplanes not provided for in reference 6.

The present investigation was also intended to be extensive enough to determine the configurations most likely to meet the spin-recovery requirements of reference 3. The requirements are summarized briefly as follows:

For an airplane licensed in the normal category:

(1) A $1\frac{1}{2}$-turn recovery after a 1-turn spin by releasing controls (controls assisted to extent necessary to overcome friction)

(2) "Uncontrollable spin" check - airplane capable of recovering from a 1-turn spin with ailerons at neutral by first completely reversing elevator and then, if necessary, fully reversing the rudder

For airplanes licensed in the acrobatic category:

(1) A 4-turn recovery after 6 turns of the spin by releasing controls

(2) Recovery from a 6-turn spin in $1\frac{1}{2}$ additional turns after neutralization of rudder and elevator, ailerons at neutral

(3) "Uncontrollable spin" check - airplane capable of recovering from a 6-turn spin with ailerons at neutral by first completely reversing elevator and then, if necessary, fully reversing the rudder

(4) Recovery from "abnormal spins" - a 2-turn recovery after 6 turns of the spin with ailerons initially either full with or full against the spin by neutralizing ailerons and fully reversing rudder and elevator

(5) A $1\frac{1}{2}$-turn recovery from a 1-turn spin by neutralization of rudder and elevator with flaps and landing gear extended

The results of the investigation presented herein are not rigidly applicable to the requirements of reference 3 for airplanes certified in the normal category because an airplane is still in the incipient phase of the spin at the end of 1 turn, whereas the model test data are obtained for the fully developed spin. Inasmuch as recovery is usually much more readily obtained from an incipient spin than from a fully developed spin, the data presented herein are probably somewhat conservative for airplanes that are to be certified in the normal category. For airplanes certified in the acrobatic category, however, the data are generally applicable because an airplane is considered to be in a fully developed spin after 6 turns.

The number of turns required for the model to recover from spins by movement of the controls is not taken as an exact indication of the number of turns required for recovery of a corresponding airplane. A corresponding airplane would be expected to recovery satisfactorily, however, in those instances in which the model recovers within $2\frac{1}{4}$ turns. Inasmuch as the number of turns acceptable for satisfactory recovery is different for each of the various spin requirements of reference 3, and inasmuch as the controls on the model used in this investigation were moved somewhat differently from the control movements specified in reference 3, it was necessary to have some means for interpreting the model data in terms of the airplane requirements. The full-size airplane requirement and the corresponding model condition used in this investigation are tabulated as follows:

Requirement for airplane	Corresponding model condition
Recovery within $1\frac{1}{2}$ turns by neutralization of rudder and elevator	Recovery in $2\frac{1}{4}$ turns or less by simultaneous neutralization of rudder and elevator, ailerons set 1/3 with or against the spin and elevator set either full up or at 2/3 its full-up deflection
Uncontrollable spin check - recovery by first reversing elevator and then, if necessary, reversing rudder	Model either incapable of spinning with elevator down, ailerons displaced somewhat from neutral, and rudder full with the spin or capable of recovery within $2\frac{1}{4}$ turns after rudder reversal with elevator full down and ailerons displaced somewhat from neutral
Recovery from abnormal spins - recovery in 2 turns by neutralization of ailerons (from full-with or full-against settings) and reversal of rudder and elevator	Recovery by simultaneous full reversal of rudder and elevator within $2\frac{1}{4}$ turns from spins with elevator set to full up and the ailerons set full with or full against the spin

Although no recoveries were attempted by releasing controls, the tests conducted by movement of the rudder from initial settings 30° and 15° with the spin to neutral and against the spin indicate the nature of the result that might be expected for 5 different floating positions of the rudder after control release: 30° and 15° with the spin, neutral, and 15° and 30° against the spin. Recoveries by releasing controls were not attempted on the model because it was believed that the results so obtained would not give an accurate indication of recoveries that might be expected on a corresponding airplane after control release for the

following reasons: The control surfaces of the model were not ballasted to simulate full-size control surfaces, the frictional forces between the model and the corresponding full-scale airplane would probably be different, and the hinge-moment characteristics of the small model control surfaces might be appreciably different from those of a full-scale airplane. In addition, the recovery characteristics of a model obtained by a positive control movement are little affected by the aerodynamic balance on the control surfaces; whereas the type of aerodynamic balance might greatly influence the recovery characteristics obtained when the controls are released. Thus it appears that the recovery results presented herein obtained by movement of the controls can be applied to estimate the recovery characteristics of a similar airplane, regardless of the type of aerodynamic balance on the control surfaces, provided the floating characteristics of the controls on the full-scale airplane are known. Floating characteristics for certain control surfaces at spinning attitudes as obtained from static data are given in references 7 and 8.

It should be noted that the rudder was moved rapidly to a given setting, the elevator and the ailerons being set to predetermined settings, for these tests, whereas the control-surface movements of a full-scale airplane after control release may be changing continuously as the air flow about the control surfaces changes during the recovery process. Nevertheless, it is believed that some indication of the positions to which the controls must float for recovery is given by the test data.

PRECISION

The spin results presented herein are believed to be the true values given by the model within the following limits:

α, degrees . . . . ±1
ϕ, degrees . . . . ±1
V, percent . . . . ±5
Ω, percent . . . . ±2

Turns for recovery:
When obtained from motion-picture records . . . . ±1/4
When obtained by visual estimate . . . . ±1/2

The preceding limits may have been exceeded for certain spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

Comparison between model and airplane spin results (reference 9) indicates that spin-tunnel results satisfactorily predict full-scale recovery characteristics 90 percent of the time and that, for the remaining 10 percent, the model results are of value in predicting some of the details of the full-scale spins. In general, when the model spun at an angle of attack less than 45° the corresponding airplane spun at a flatter angle of attack, and when the model spun at an angle of attack greater than 45° the corresponding airplane spun at a steeper attitude. The comparison presented in reference 9 also indicated that generally the model inner wing was tilted less downward and the altitude loss per revolution was less than that of the corresponding airplane. It was also indicated that the corresponding airplane would spin at greater or lower rates of rotation than the model, depending on whether the tail-damping ratio (reference 2) was greater or less than 0.02, respectively.

Because of the limits of accuracy within which the model could be ballasted and because of inadvertent damage to the model during tests, the measured weight and mass distribution of the model varied from the selected values by the following amounts:

Weight, percent	1 low to 4 high
Center-of-gravity location, percent $\bar{c}$	2 forward to 3 rearward
Moments of inertia:	
I_X, percent	0 low to 10 high
I_Y, percent	2 low to 6 high
I_Z, percent	1 low to 9 high

The accuracy of measuring the weight and mass distribution of the model is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Control settings were made with an accuracy of $\pm 1^{\circ}$.

TEST CONDITIONS

Tests were performed for the model conditions listed in table III. The mass characteristics and mass parameters for the loading conditions tested on the model have been converted to corresponding full-scale values and are tabulated in table IV. For the tests, the model was ballasted with lead weights to represent the airplane at an altitude of 5,000 feet (ρ = 0.002049 slug/cu ft). The weight and moments of inertia of the model were selected on the basis of dimensions of an airplane

typical of this type. Loadings 1 and 1' in table IV correspond closely to normal distributions of mass for an airplane proportioned similar to the model, but loadings 2 and 2' (mass extended along the fuselage and retracted along the wings) correspond to a mass change from the normal loading condition or to a loading that might normally be expected for an airplane having a relatively longer fuselage than the model. Loading 1 is referred to herein as the normal loading.

Each configuration tested on the model was usually tested with two maximum rudder deflections: 30° right to 30° left and 15° right to 15° left. The rudder was also neutralized from initial settings 30° and 15° with the spin. The maximum control deflections used for the ailerons and elevator were:

Elevator	
Up, degrees	30
Down, degrees	20
Ailerons	
Up, degrees	20
Down, degrees	20

The intermediate elevator and aileron deflections used are indicated in the charts.

Although the range of tail-damping power factor investigated extended from 0 to 1200×10^{-6}, most of the tests were conducted for two tail-damping power factors, 50×10^{-6} and 600×10^{-6}. In addition, most of the investigation was conducted with the rectangular wing with round tips installed on the model, and only random checks were conducted with the other wing arrangements installed.

RESULTS AND DISCUSSION

The results of the spin tests of the model are presented in charts 1 to 69 and in table V. The model spin data are presented in terms of the full-scale values for a corresponding airplane at a test altitude of 5,000 feet. The results of the tests are arbitrarily presented in terms of equivalent right spins, that is, for the airplane turning to the pilot's right. Unless otherwise indicated, the data discussed herein are for the following model configuration: the rectangular wing with round tips shown in figure 2 and the normal tail shown in figure 3 and table I.

In some cases, the only steady-spin data that are presented in the charts for certain spin control configurations are the values of the vertical velocity. The data were limited to the vertical velocity in instances when the nature of the spin was so wandering or the spin radius so wide that the model could not be maintained in the tunnel long enough to obtain any of the other spin data or when the motion-picture records were not clear. Additional data for these spins can be obtained from figures 11 and 12 which were prepared from all the test data and indicate the approximate angle of attack and the approximate rate of rotation that may be expected for a given control setting at a given loading condition provided the rate of vertical descent is known. The plot of vertical velocity against angle of attack in figure 11 is analogous to plotting drag coefficient against angle of attack inasmuch as the weight of the model and the density of the air during the investigation remained nearly constant. Data in figure 11 check very closely with similar data presented in reference 10 for a group of different monoplane models having wings and fuselages of proportions similar to the present model, and comparison of these data indicate that drag coefficient in spins is relatively independent of sideslip, rate of rotation, and, to some extent, model configuration. Figure 12 presents the approximate rate of rotation plotted against the angle of attack for various elevator settings. By use of Euler's equation of motion

$$\Omega^2 = \frac{-M}{\frac{1}{2}(I_Z - I_X) \sin 2\alpha}$$

the rate of rotation in steady spins is shown to be a function of the aerodynamic pitching moment and angle of attack for a body having constant moments of inertia. Inasmuch as unpublished spinning-balance data for a model of proportions similar to the present model indicate that the aerodynamic pitching moment was generally only little affected by sideslip in a spin, the plot presented in figure 12 seems to be justifiable.

For this model the helix angle, the angle between the flight path and the vertical, was approximately 9°. The angle of sideslip at the center of gravity equals the angle between the span axis and horizontal (ϕ) minus the helix angle. (Sideslip at the center of gravity of a model in a spin is inward when the inner wing is down by an amount greater than the helix angle.)

Effect of Variation in Tail-Damping Power Factor for the Normal Loading and Normal Tail

The results of the model tests obtained with the normal horizontal tail installed at various vertical positions on the normal vertical tail are shown in charts 1 to 6 for the normal loading $\left(\frac{I_X - I_Y}{mb^2} = 0\text{, center of gravity at 25 percent } \bar{c}\right)$.

As might have been anticipated from reference 11, which indicates the relative effectiveness of the controls for various mass distributions, the data indicate that setting the elevator up and the ailerons with the spin tended to flatten the spin and retard the recoveries attempted by reversal of the rudder alone; whereas elevator-down and aileron-against settings were the most favorable control settings for recovery. For this relatively forward center-of-gravity position (25 percent $\bar{c}$) and for this distribution of mass $\left(\frac{I_X - I_Y}{mb^2} = 0\right)$, recoveries by reversal of the rudder alone appeared to be little affected by an increase of the tail-damping power factor from a low tail-damping power factor of 50×10^{-6} to the high tail-damping power factor of 600×10^{-6}. The test data indicate that a corresponding airplane utilizing a rudder deflection of $\pm 30^{\circ}$ will probably not recover satisfactorily by rudder reversal alone unless the tail-damping power factor is somewhat in excess of 1200×10^{-6}. This value is based on the spin-tunnel criterion requiring recovery in $2\frac{1}{4}$ turns by rudder reversal alone to only 2/3 of its full deflection against the spin when the ailerons are deviated somewhat from neutral (1/3 with the spin, the adverse setting for this loading). It should be noted that the other spin-tunnel criterion previously discussed requiring satisfactory recovery by full rudder reversal from all aileron-neutral spins apparently is the less rigid of the two criterions, especially when the rudder movement is $\pm 30^{\circ}$. It should also be noted that although limiting the rudder deflection to $\pm 15^{\circ}$ steepened the spin somewhat, both of the aforementioned criterions apparently became more difficult to meet. The data indicate that by increasing the tail-damping power factor to 1200×10^{-6} satisfactory recoveries could be obtained by rudder reversal to 15° against the spin from all aileron-neutral spins, but the tests were not extensive enough to indicate the tail-damping power factor required for meeting the other spin criterion for the $\pm 15^{\circ}$ rudder deflection. Although the tail-damping power factors required for satisfactory recovery by rudder reversal alone are indicated to be excessively large to satisfy both spin-tunnel criterions, the data show that a corresponding full-scale airplane proportioned similar to the model would be expected to have satisfactory spin-recovery

characteristics for a tail-damping power factor as low as 50×10^{-6}, even when the rudder deflection is reduced to $\pm 15^{\circ}$, by normal use of the controls (full reversal of the rudder followed approximately 1/2 turn later by movement of the elevator to full down).

An increase in tail-damping power factor from 50×10^{-6} to as much as 1200×10^{-6} was indicated to have little effect on the recoveries obtained by neutralization of the rudder. The data indicate that satisfactory recoveries could be obtained by neutralization of the rudder, provided either the ailerons were moved to against the spin or the elevator was moved downward to neutral or to somewhat beyond neutral, depending on the amount of aileron deflection with the spin. Similar results were obtained by neutralizing the rudder from an initial rudder setting either 30° or 15° with the spin.

Effect of Changing the Mass Distribution

Comparison of charts 7 to 16 with charts 1 to 6 shows the manner in which the spin and recovery characteristics were affected by extending mass along the fuselage and retracting mass along the wings (loading 2). This loading may occur on an airplane having proportions similar to those of the model used in the investigation when weight is added to the fuselage and when fuel in the wings is consumed. On the other hand, loading 2 might be expected to be a more nearly normal loading for a single-engine airplane having a relatively longer fuselage length compared with the wing span than the present model. If this increase in fuselage length should be primarily an increase in tail length, the data presented herein would be expected to be somewhat conservative. (See reference 12.)

Comparison of charts 7 to 16 with charts 1 to 4 indicates that extending mass along the fuselage and retracting mass along the wings generally flattened the spin somewhat and decreased the rate of rotation, particularly when the initial rudder setting was 30° with the spin. In addition, although increasing the tail-damping power factor had little effect on the spin-recovery characteristics at the normal loading, changes in tail-damping power factor had an appreciable effect on the spin-recovery characteristics at this loading. The relative effects of ailerons and elevator on the spin-recovery characteristics were now found to be quite different from those obtained at the normal loading for low values of the tail-damping power factor; however, for high values of the tail-damping power factor the relative effects of ailerons and elevator were not appreciably changed. As can be seen from the data presented in chart 7 for a tail-damping power factor of 50×10^{-6}, setting the ailerons with the spin generally led to the steepest spins and this setting was usually the most favorable for recovery;

aileron-against settings generally led to flatter spins and had an adverse effect on recoveries for a ±30° rudder deflection. These effects are the reverse of those obtained with the normal loading. When the rudder deflection was limited to only ±15°, however, the results presented in chart 8 indicate that aileron-with settings had an adverse effect on recoveries for up settings of the elevator. Steep spins and fast recoveries were still obtained when the ailerons were displaced full with the spin for elevator neutral and down settings, however.

According to the study presented in reference 11, it would have been expected that the spin control configuration with the elevator up and ailerons with the spin might always be the most favorable control setting for recovery for this loading $\left(\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}\right)$ because the attitude of the model at this control setting and the loading of the model are such that the inertia yawing moment (approx. equivalent to $(I_X - I_Y)\,\Omega^2 \cos\alpha \sin\phi$ in a steady spin) will be the most negative for this control setting and will act in a sense to oppose the spin. Reference 11 also indicates that for this loading, when the elevator is down and the ailerons are against the spin, the inertia yawing moment is such as to aid the spin and retard recoveries; this result is true for these tests. The poor recoveries obtained from the elevator-up and aileron-with spins by rudder reversal from 15° with to 15° against the spin might be attributable to the fact that reduction in the rudder deflection from 30° to 15° with the spin resulted in less outward sideslip at the tail. This reduction in outward sideslip in combination with the reduced rudder deflection apparently reduced the effectiveness of the rudder in applying a yawing moment opposing the spin rotation.

The data presented in charts 7 to 16 show that as the tail-damping power factor was increased from 50×10^{-6} to 600×10^{-6} the recoveries from the elevator-down, aileron-against spin gradually improved, the recoveries being considered satisfactory by full rudder reversal to 15° or 30° against the spin for the tail-damping power factors of 200×10^{-6} and higher. Thus, despite the fact that the inertia yawing moment was aiding the spin for this control position, the aerodynamic yawing moment opposing the spin eventually became great enough to terminate the spin satisfactorily at the higher values of tail-damping power factor because of the great amount of outward sideslip at the tail for this control setting and the large effective fin and rudder area exposed to the air stream. On the other hand, it was questionable whether the recoveries were satisfactory for some of the aileron-neutral and aileron-with spins when the elevator was full up even for tail-damping power factors in excess of 50×10^{-6}, particularly for the spin with ailerons displaced 1/3 with the spin when the rudder was not quite reversed to its

full-against setting. In these instances, the model continued to turn at a stalled angle of attack after rudder reversal, but the motion could not be observed for a long enough period to determine the final outcome, usually because of the fast rate of descent and because of the wide radius and wandering nature of the spin after rudder reversal. It should be noted that these recovery attempts were by rudder reversal alone, the elevator and the ailerons being maintained at their initial full-up and full-with settings, respectively. Chart 7 indicates that, for the tail-damping power factor of 50×10^{-6}, the recoveries attempted by simultaneous full reversal of rudder to 30° against the spin and movement of the elevator to 20° down from all elevator-up spins were rapid. The data trends for the other tail-damping power factors investigated also indicate that, regardless of whether the rudder is deflected to 30° or 15° against the spin for recovery, movement of the elevator down after rudder reversal would have enabled the model to recover rapidly for the range of tail-damping power factors investigated. The results obtained at this loading when a larger horizontal tail was installed on the model (chart 54) and the similarity of the spin and recovery characteristics to those obtained for the normal tail (compare charts 54 and 15) also indicate that clearly defined recoveries would have been obtained from aileron-with, elevator-up spins with the normal tail installed on the model, regardless of the value of the tail-damping power factor, by neutralization of the ailerons in conjunction with reversal of the rudder to 30° against the spin.

Charts 7 to 16 indicate that the effects of reducing the rudder deflection from $\pm 30^{\circ}$ to $\pm 15^{\circ}$ for this loading were similar to those noted for the normal loading. As was the case for the normal loading, the model results indicate that the recovery characteristics of a similar full-scale airplane should be satisfactory by normal use of the controls (rudder reversal followed approx. 1/2 turn later by elevator reversal) for tail-damping power factors even as low as 50×10^{-6}. The recovery characteristics by neutralization of the rudder were somewhat similar to those obtained at the normal loading except that poor recoveries were now indicated to be obtained for aileron-against and elevator-down settings for low values of tail-damping power factor.

Effect of Moving the Center of Gravity Rearward

The data presented in charts 17 to 25 show the results obtained with the center of gravity positioned at 40 percent of the mean aerodynamic chord. Comparison of these data with the data presented in charts 1 to 16 indicate that for either loading a rearward movement of the center of gravity from 25 to 40 percent of the mean aerodynamic chord generally flattened the spin attitude somewhat and decreased the rate of rotation. The relative effects of elevator, ailerons, and tail-damping power factor on the recoveries obtained by reversal of the

rudder alone ($\pm30^\circ$ or $\pm15^\circ$) were indicated to be approximately the same as obtained at the 25-percent mean-aerodynamic-chord location except that recoveries were generally improved from spins with the elevator at near full up when ailerons were partially or full with the spin. These data also indicate that recoveries by normal use of controls (rudder reversal followed approximately 1/2 turn later by movement of the elevator to full down) should enable a corresponding airplane to recover satisfactorily for tail-damping power factors even as low as 50×10^{-6}, as was the case for the normal center-of-gravity location. The data indicate that, when the center of gravity was moved rearward from 25 percent (normal) to 40 percent of the mean aerodynamic chord and the rudder was only neutralized for recovery, poor recoveries were extended to further downward settings of the elevator. (Compare charts 1 to 4, 7, 8, 15, and 16 with charts 17 to 20 and 22 to 25.) The rudder-neutralization tests also indicate that increasing the tail-damping power factor by raising the position of the horizontal tail on the vertical tail also caused poor recoveries to extend to lower elevator settings when the center of gravity was placed at 40 percent of the mean aerodynamic chord. (Compare charts 17, 18, 22, and 23 with charts 19, 20, 24, and 25.) Thus, raising the horizontal tail on the vertical tail when the center of gravity is at a rearward position seems to have the same effect as an additional rearward movement of the center of gravity. Spinning-force data presented in reference 13 for a model of proportions similar to the model used in the present investigation substantiate this opinion inasmuch as it is indicated that a horizontal tail mounted at a low position on the vertical tail for a low-wing model usually contributes a more-nose-down pitching moment at spin attitudes than when it is mounted at a high position on the vertical tail.

The data presented in the aforementioned charts indicate that neutralization of rudder and elevator (elevator and aileron settings initially deviated slightly from the normal spin control configuration) led to satisfactory recoveries for low and high values of tail-damping power factor for the normal center-of-gravity position, but the data obtained with the center of gravity at 40 percent of the mean aerodynamic chord indicate that neutralization of rudder and elevator would result in satisfactory recovery characteristics only for low positions of the horizontal tail on the vertical tail (low values of the tail-damping power factor). Examination of the low-wing model used in the investigation reported in reference 13 and the low-wing model used in the present investigation indicates that this result is probably attributable to wing interference effects, a low horizontal tail being less affected by the influence of the wing at spinning attitudes than a high horizontal tail. Thus it might be expected that, if the wing were installed at a high position on the fuselage, recoveries by simultaneous neutralization of rudder and elevator might not be so critically dependent on the horizontal-tail height. Analysis of the spin-model data and the force data presented in reference 13 indicates that if the tail-damping power

factor had been increased on the present model by means other than by raising the position of the horizontal tail on the vertical tail (by adding ventral-fin area or by increasing tail length, for example) recoveries by simultaneous neutralization of rudder and elevator for high tail-damping power factors would be expected to be as good as or better than those obtained for low values of the tail-damping power factor.

Effect of Changing the Tail Size and Tail Arrangement

The effect on the model spin and recovery characteristics of replacing the normal vertical and horizontal tails by different tail arrangements are indicated in the following charts: normal vertical tail replaced by a large vertical tail (2-series tails, fig. 4), charts 26 to 35; normal vertical tail replaced by a tail of the same size but having a partial-length rudder (3-series tails, fig. 5), charts 36 to 43; normal horizontal tail replaced by a large horizontal tail (4-series tails, fig. 6), charts 44 to 57; and normal vertical tail replaced by a tail of similar size but having a partial-length rudder with the normal horizontal tail moved rearward (5-series tails, fig. 7), charts 58 to 63.

The results of these tests indicate that the model recovery characteristics were somewhat similar to those obtained when the normal vertical and horizontal tails were installed on the model. The most noticeable change in the model spin recoveries occurred for the loading with mass extended along the fuselage and retracted along the wings $\left(\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}\right)$ for low values of the tail-damping power factor; the data indicate that the large vertical tail and the tails having a partial-length rudder generally had favorable effects on recoveries attempted by full reversal of the rudder from the aileron-against, elevator-down spins, whereas the large horizontal tail affected recoveries from these spins adversely.

The data obtained for the rearward center-of-gravity position indicate that, although recoveries by simultaneous neutralization of rudder and elevator were satisfactory for the normal tail for a tail-damping power factor of 50×10^{-6} and unsatisfactory for higher values of the tail-damping power factor, when the large vertical tail (2-series tails) was installed or when the full-length rudder was replaced with a partial-length rudder (3-series tails) unsatisfactory recoveries were now obtained even for a tail-damping power factor as low as 50×10^{-6}. As has been explained previously for the normal tail, a low horizontal-tail position apparently contributed a more-nose-down pitching moment and was more effective in bringing about recovery by simultaneous

neutralization of rudder and elevator than a high horizontal-tail position for rearward positions of the center of gravity. Thus the poor recoveries obtained when the partial-length rudder was installed on the model for the tail-damping power factor of 50×10^{-6} may be attributable to the fact that the horizontal tail had to be mounted at a relatively high position on the vertical tail to obtain this value of tail-damping power factor (see table I and fig. 5). Data presented in table V substantiate this opinion inasmuch as it is shown that when the horizontal tail was lowered to the bottom of the fuselage, making the tail-damping power factor 0 for the tail having the partial rudder (tail 3x), recoveries by simultaneous neutralization of rudder and elevator were indicated to be satisfactory. The fact that the model did not recover satisfactorily by neutralization of rudder and elevator for the tail-damping power factor of 50×10^{-6} when the large vertical tail was installed may be attributable to the relatively flat spins obtained which made the controls somewhat ineffective in terminating spins.

Effect of Wing Shape

Most of the investigation made to determine the effects of the different wing plan forms was performed for only the normal-tail configuration installed on the model and for a tail-damping power factor of 50×10^{-6} (tail 1a in fig. 3) inasmuch as it was felt that any differences in the results for the different wing plan forms would be manifested for this tail arrangement. Brief tests were also made with the tail arrangement having the normal horizontal tail replaced by a large horizontal tail. As is shown by charts 50 to 53 and by comparison of charts 64 to 69 with charts 7, 8, 17, and 18, the model spin and recovery characteristics were essentially the same regardless of whether the rectangular wing with either round or square tips or the tapered wing with either round or square tips (fig. 2) was installed on the model. Previous spin-tunnel data (references 14 to 18) indicate that a rectangular wing with a square tip generally gave faster recoveries than either a round-tip tapered wing or a rectangular wing with a round tip. Comparison of the current model with the model used in the previously reported investigations indicates that the current model more nearly simulated a present-day personal-owner airplane as regards the over-all proportions, relative density μ, and moments of inertia and also that the current model had 6° positive dihedral in the wing, whereas the previously investigated model had no dihedral. In addition, no data are presented in references 14 to 18 for any aileron-with or aileron-against spins so that the control configurations for which the data can be compared are limited to only aileron-neutral spins. In view of these differences, the results obtained for the current investigation are expected to be more nearly applicable for present-day personal-owner airplanes than the previously reported data.

Application to Various Recovery Techniques

The results of the investigation presented herein are generally applicable when recovery is attempted from fully developed spins but the data are considered conservative for recovery attempts made from incipient spins. (As stated previously, an airplane is still in the incipient phase of the spin at the end of 1 turn.)

Recovery by releasing controls.- A simplified summary of the results showing aileron-elevator combinations estimated to give probable good and bad recoveries for five floating positions of the rudder following release of the controls is shown in figures 13 to 16 for the normal tail (1-series tails, fig. 3). To be conservative, recoveries of a questionable nature are indicated as being unsatisfactory. Inasmuch as conventional ailerons tend to float with the spin and conventional elevators tend to float at up positions after control release from spinning attitudes, the information presented in figures 13 to 16 indicate that it is desirable to have the rudder on a corresponding airplane float as far against the spin as possible in order to obtain recoveries from spins by releasing controls. If the rudder floats only to neutral after control release and the assumption is made that the ailerons float somewhat with the spin, figures 13 to 16 show that the elevator must float to near neutral for a normal position of the center of gravity and to below neutral for rearward positions of the center of gravity, particularly for the higher values of the tail-damping power factor. It should be noted that the one instance when elevator-full-up floating tendencies were indicated to be desirable was for the rearward center-of-gravity position (figs. 15 and 16), provided the ailerons did not float with the spin and the rudder floated to at least neutral after control release. For the normal distribution of mass $\left(\frac{I_X - I_Y}{mb^2} = 0\right)$, aileron-against and elevator-down floating tendencies were desirable and were indicated to lead to satisfactory recoveries for all tail-damping power factors even though the rudder may float as much as 30° with the spin for a forward position of the center of gravity (fig. 13) and as much as 15° with the spin for a rearward position of the center of gravity (fig. 15). For the loading condition having mass extended along the fuselage and retracted along the wings $\left(\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}\right)$ aileron-against, elevator-down configurations were indicated to have an adverse effect on recoveries for low values of the tail-damping power factor but were indicated to have a favorable effect for high values of the tail-damping power factor, provided the rudder floats to neutral or against the spin after control release (figs. 14 and 16).

Information presented in reference 7 indicates that the most desirable type of rudder balance for obtaining rudder floating angles against the spin appears to be a horn balance, that a nose overhang balance will tend to increase the elevator-up floating tendencies, and

that a beveled trailing edge will decrease the elevator-up floating tendencies at spinning attitudes. In addition, it appears that by substituting spoiler ailerons for the conventional ailerons the adverse effects encountered by conventional ailerons floating with the spin would be reduced, inasmuch as it is believed that spoiler ailerons would tend to float less with the spin after the stick is released.

The data indicate that with the other tails installed the recovery characteristics by control release would be approximately as indicated for the normal tail. It should be noted, however, that even for the loading condition having mass extended along the fuselage and retracted along the wings $\left(\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}\right)$ elevator-down and aileron-against-the-spin floating tendencies were indicated to lead to satisfactory recoveries though the rudder may float as much as 15° with the spin for low as well as for high values of tail-damping power factor when the large vertical tail was installed on the model. Similar results were obtained when the tail with the partial-length rudder having a tail-damping power factor of 600×10^{-6} was installed on the model (tail 3e). These results are probably attributable to the fact that, because of the outward sideslip induced by setting the elevator to down and the ailerons against the spin, there was a large aerodynamic yawing moment opposing the spin for these tail configurations when the rudder deflection was limited to only 15° with the spin.

Recovery from uncontrollable and abnormal spins.- The data presented in the charts indicate that no difficulty will be encountered in recovering from abnormal spins for any of the loadings, tail-damping power factors, or tail variations investigated, provided elevator reversal does not precede the reversal of the rudder during the recovery procedure. The technique specified for recovery from abnormal spins is neutralization of ailerons and full reversal of rudder and elevator, ailerons initially displaced full with or full against the spin. The data further indicate that high values of the tail-damping power factor will lead to satisfactory recoveries from abnormal spins even though the elevator reversal may precede rudder reversal.

It was indicated that unsatisfactory recoveries might be obtained from uncontrollable spins on a corresponding airplane (recovery from aileron-neutral spins required by reversing elevator followed by rudder reversal if necessary) for the loading condition having the mass extended along the fuselage and retracted along the wings $\left(\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}\right)$

for the normal tail unless the tail-damping power factor is at least of the order of 100×10^{-6} to 200×10^{-6}. Unsatisfactory recoveries may also be obtained from uncontrollable spins for this loading for the large-horizontal-tail arrangement unless the tail-damping power factor is somewhat in excess of 300×10^{-6}. For the normal distribution of mass $\left(\frac{I_X - I_Y}{mb^2} = 0\right)$, satisfactory recoveries were indicated to be obtained from uncontrollable spins for all tails and tail-damping power factors by reversal of both elevator and rudder for a $\pm 30^{\circ}$ rudder deflection and by reversal of the elevator alone when the rudder deflection was limited to $\pm 15^{\circ}$.

Recovery by neutralization of rudder and elevator.- The data presented in the charts, table V, and figure 17 indicate that for the range of tail-damping power factors and the tail configurations investigated, satisfactory recoveries will be obtained by neutralization of rudder and elevator if the center of gravity is maintained at a forward position. For rearward positions of the center of gravity, recoveries by neutralization of rudder and elevator were indicated to be satisfactory for tail-damping power factors of 50×10^{-6} but probably unsatisfactory for higher values of the tail-damping power factor, with the exception of the 2-series tails (large vertical tail) and the 3-series tails (partial-length rudder), which were indicated to lead to unsatisfactory recoveries for tail-damping power factors of 50×10^{-6} as well as for higher values of the tail-damping power factor. As has been explained previously, the high tail-damping power factors were not so effective as the low tail-damping power factors for this particular manipulation of the controls probably because of the effect of horizontal-tail height on the pitching moment, the low horizontal-tail positions (low tail-damping power factors) giving a more-nose-down pitching moment than the high horizontal-tail positions (high tail-damping power factors). Table V and figure 17 show that, when the horizontal tail was lowered to near the bottom of the fuselage on the 3-series tails (partial-length rudder) so that the tail-damping power factor became 0, satisfactory recoveries were indicated. No tests were conducted on the 2-series tails (large vertical tail) for a tail-damping power factor smaller than 50×10^{-6}.

The data presented in the charts indicate that, if the elevator had been moved to somewhat beyond neutral in conjunction with rudder neutralization, recoveries would have been satisfactory for high values of the tail-damping power factor and a rearward center-of-gravity position. Thus, inasmuch as the horizontal-tail incidence on the model investigated was 0°, it would be expected that, if the horizontal tail on a corresponding airplane is set at positive incidence, satisfactory recovery by simultaneous neutralization of rudder and elevator would be expected to

extend to values of tail-damping power factor higher than previously noted for a rearward center-of-gravity position.

Recovery by full reversal of rudder and elevator.- The results of the investigation show that satisfactory recoveries will be obtained by full reversal of rudder and elevator for all the tail configurations and loadings investigated, provided the recovery technique used is full rapid rudder reversal followed approximately 1/2 turn later by forward movement of the stick. If the stick is moved forward before the rudder is reversed, however, slow recoveries may be obtained on a corresponding airplane for the loading condition having mass extended along the fuselage and retracted along the wings $\left(\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}\right)$ for the normal-tail arrangement unless the tail-damping power factor is at least 100×10^{-6} to 200×10^{-6} and for the large-horizontal-tail configuration unless the tail-damping power factor is somewhat greater than 300×10^{-6}. For the normal-loading condition $\left(\frac{I_X - I_Y}{mb^2} = 0\right)$ satisfactory recoveries were indicated to be obtainable for all tail configurations even though the stick is moved forward prior to reversal of the rudder.

CONCLUSIONS

Based on the results of a spin-tunnel investigation of a low-wing model typical of present-day four-place personal-owner airplane designs, the following conclusions are drawn:

1. The tail-damping power factors required for satisfactory recovery were indicated to be small, provided the recovery technique used is full rapid rudder reversal followed approximately 1/2 turn later by reversal of the elevator; however, a large tail-damping power factor might be desirable to avoid any adverse effects that might be encountered by a premature movement of the elevator to down.

2. Setting the ailerons against the spin and setting the elevator to full down were the most favorable control settings for recovery for the normal distribution of mass. When the mass was extended along the fuselage and retracted along the wings, the aileron and elevator effects for high values of tail-damping power factor were similar to those noted for the normal mass distribution, but for the low values of tail-damping power factor aileron-with and elevator-up settings were now generally beneficial, particularly for the $\pm 30^{\circ}$ rudder deflection.

3. Changes in the vertical- and horizontal-tail design usually had little effect on the model recovery characteristics for high values of the tail-damping power factor. For low values of tail-damping power factor the most noticeable differences in spin-recovery characteristics brought about by changes in tail design occurred for the loading having mass extended along the fuselage and retracted along the wings.

4. Reducing the rudder deflection from $\pm 30^{\circ}$ to $\pm 15^{\circ}$ usually steepened the spin somewhat but generally had little effect on the spin-recovery characteristics.

5. Moving the center of gravity rearward generally flattened the spin and reduced the rate of rotation. Recoveries attempted by full reversal of rudder generally were little affected by the center-of-gravity position.

6. Installing square wing tips in place of the round tips on the rectangular wing or replacing the rectangular wing with a wing having a taper ratio of 2:1 had little effect on the spin and recovery characteristics.

7. An important design condition necessary to enable recovery from spins by releasing controls is that the rudder be designed to float to large deflections against the spin.

8. No difficulty should be encountered in recovering from abnormal spins (ailerons maintained full with or full against the spin during the steady spin), provided rudder reversal precedes the reversal of the elevator.

9. A high value of the tail-damping power factor will generally be desirable for satisfactory recovery from uncontrollable spins (elevator reversed first for recovery followed by rudder reversal if necessary) for the loading having mass extended along the fuselage and retracted along the wings. For the normal distribution of mass no difficulty will be encountered in recovering from uncontrollable spins.

10. No difficulty will be experienced in recovery from spins by neutralization of rudder and elevator for forward positions of the center of gravity. For rearward positions of the center of gravity, a low position of the horizontal tail on the vertical tail (low tail-damping power factor) will be desirable for recovery.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., September 7, 1950

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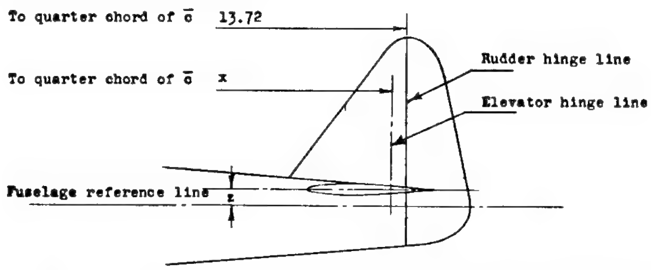
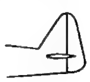
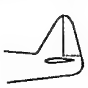
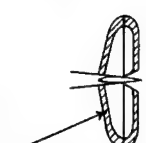
TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE TAIL CONFIGURATIONS INVESTIGATED



Tail description	Tail	Tail-damping power factor	Horizontal tail				Vertical tail				x (in.)	z (in.) (a)	Figure
			Size	Stabilizer area (sq in.)	Elevator area (sq in.)	Aspect ratio	Size	Fin area (sq in.)	Rudder area (sq in.)	Aspect ratio			
Normal tail 	1a	50×10^{-6}	Normal	14.4	10.32	3.98	Normal	6.07	6.07	1.26	13.28	0.22	3
	1b	100	Normal	14.4	10.32	3.98	Normal	6.07	6.07	1.26	13.28	-.16	3
	1c	200	Normal	14.4	10.32	3.98	Normal	6.07	6.07	1.26	13.28	-.65	3
	1d	300	Normal	14.4	10.32	3.98	Normal	6.07	6.07	1.26	13.28	-1.00	3
	1e	600	Normal	14.4	10.32	3.98	Normal	6.07	6.07	1.26	13.28	-1.87	3
	1f	1200	Normal	14.4	10.32	3.98	Normal tail plus ventral fin and rudder	[b]8.45	7.83	1.26	13.28	-1.87	3
Large vertical tail 	2a	50	Normal	14.4	10.32	3.98	Large	11.50	11.5	2.0	13.28	.65	4
	2c	300	Normal	14.4	10.32	3.98	Large	11.50	11.5	2.0	13.28	0	4
	2e	600	Normal	14.4	10.32	3.98	Large	11.50	11.5	2.0	13.28	-1.21	4
Partial-length rudder 	3a	50	Normal	14.4	10.32	3.98	Normal	6.07	3.97	1.26	13.28	-.50	5
	3e	600	Normal	14.4	10.32	3.98	Normal	6.07	3.97	1.26	13.28	-2.70	5
	3x	0	Normal	14.4	10.32	3.98	Normal	6.07	3.97	1.26	13.28	.75	5
Large horizontal tail  Area added	4a	50	Large	20.68	14.52	4.00	Normal	6.07	6.07	1.26	13.28	.20	6
	4c	200	Large	20.68	14.52	4.00	Normal	6.07	6.07	1.26	13.28	-.50	6
	4d	300	Large	20.68	14.52	4.00	Normal	6.07	6.07	1.26	13.28	-.83	6
	4e	600	Large	20.68	14.52	4.00	Normal	6.07	6.07	1.26	13.28	-1.65	6
Horizontal tail moved rearward and partial-length rudder 	5a	50	Normal	14.4	10.32	3.98	Normal	6.07	3.97	1.26	14.78	.33	7
	5b	100	Normal	14.4	10.32	3.98	Normal	6.07	3.97	1.26	14.78	-.35	7

[a]A positive value of z indicates horizontal tail below fuselage reference line.
[b]Includes ventral-fin area.

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TABLE II.- DIMENSIONAL CHARACTERISTICS OF THE CORRESPONDING FULL-SCALE AIRPLANE EQUIPPED WITH THE 1-SERIES TAILS

Over-all length, ft	22.37
Wing:	
Airfoil section	NACA 23012
Incidence, deg	3
Dihedral, deg	6
Twist, deg	0
Rectangular wing:	
Span, ft	33.63
Mean aerodynamic chord, $\bar{c}$:	
Round tip, ft	4.89
Square tip, ft	4.99
Leading edge of $\bar{c}$ rearward of leading edge of wing:	
Round tip, ft	0.05
Square tip, ft	0
Taper ratio	1.00
Area:	
Round tip, sq ft	163.28
Square tip, sq ft	168.61
Aspect ratio:	
Round tip	6.93
Square tip	6.71
Tapered wing:	
Span, ft	33.63
Mean aerodynamic chord, $\bar{c}$:	
Round tip, ft	5.08
Square tip, ft	5.09
Leading edge of $\bar{c}$ rearward of leading edge of root chord, ft	0.73
Taper ratio	2.00
Area:	
Round tip, sq ft	163.22
Square tip, sq ft	166.23
Aspect ratio:	
Round tip	6.93
Square tip	6.80

TABLE II.- DIMENSIONAL CHARACTERISTICS OF THE CORRESPONDING FULL-SCALE AIRPLANE EQUIPPED WITH THE 1-SERIES TAILS - Concluded

Ailerons:	
Span, ft	7.19
Area rearward of hinge line:	
Rectangular wing, sq ft	15.70
Tapered wing, sq ft	15.76
Aspect ratio:	
Rectangular wing	6.58
Tapered wing	6.56
Horizontal tail surface:	
Span, ft	10.25
Total area, sq ft	26.39
Elevator area rearward of hinge line, sq ft	11.02
Aspect ratio	3.98
Incidence, deg	0
Dihedral, deg	0
Distance from quarter chord of $\bar{c}$ to elevator hinge line, ft	13.73
Section	Modified NACA 0009
Vertical tail surface:	
Span, ft	5.32
Total area, sq ft	12.96
Rudder area rearward of hinge line, sq ft	6.48
Aspect ratio	1.26
Offset, deg	0
Distance from quarter chord $\bar{c}$ to rudder hinge line, ft	14.18
Section	Modified NACA 0009

TABLE III.- CONDITIONS TESTED ON THE MODEL

Test condition	Loading	$\frac{I_X - I_Y}{mb^2}$	Center-of-gravity position, $x/\bar{c}$	Wing plan form	Wing-tip shape	Tail	TDPF	Initial rudder setting, with the spin (deg)	Method employed in recovery attempt	Data presented in-
1	1	0×10^{-4}	0.25	Rectangular	Round	1a	50×10^{-6}	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 1 and table V
2	1	0	.25	----do-----	-do--	1a	50	15	Rudder reversal Rudder neutralization	Chart 2
3	1	0	.25	----do-----	-do--	1e	600	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 3 and table V
4	1	0	.25	----do-----	-do--	1e	600	15	Rudder reversal Rudder neutralization	Chart 4
5	1	0	.25	----do-----	-do--	1f	1200	30	Rudder reversal Rudder neutralization	Chart 5
6	1	0	.25	----do-----	-do--	1f	1200	15	Rudder reversal	Chart 6
7	2	-120	.25	----do-----	-do--	1a	50	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator reversal Simultaneous rudder and elevator neutralization	Chart 7 and table V
8	2	-120	.25	----do-----	-do--	1a	50	15	Rudder reversal Rudder neutralization	Chart 8
9	2	-120	.25	----do-----	-do--	1b	100	30	Rudder reversal	Chart 9
10	2	-120	.25	----do-----	-do--	1b	100	15	-----------do-----------	Chart 10
11	2	-120	.25	----do-----	-do--	1c	200	30	-----------do-----------	Chart 11
12	2	-120	.25	----do-----	-do--	1c	200	15	-----------do-----------	Chart 12
13	2	-120	.25	----do-----	-do--	1d	300	30	-----------do-----------	Chart 13
14	2	-120	.25	----do-----	-do--	1d	300	15	-----------do-----------	Chart 14
15	2	-120	.25	----do-----	-do--	1e	600	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 15 and table V
16	2	-120	.25	----do-----	-do--	1e	600	15	Rudder reversal Rudder neutralization	Chart 16
17	1'	0	.40	----do-----	-do--	1a	50	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 17 and table V
18	1'	0	.40	----do-----	-do--	1a	50	15	Rudder reversal Rudder neutralization	Chart 18
19	1'	0	.40	----do-----	-do--	1e	600	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 19 and table V
20	1'	0	.40	----do-----	-do--	1e	600	15	Rudder reversal Rudder neutralization Simultaneous rudder and elevator reversal	Chart 20
21	1'	0	.40	----do-----	-do--	1f	1200	15	Rudder reversal	Chart 21
22	2'	-120	.40	----do-----	-do--	1a	50	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 22 and table V

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TABLE III.- CONDITIONS TESTED ON THE MODEL - Continued

Test condition	Loading	$\frac{I_X - I_Y}{mb^2}$	Center-of-gravity position, $x/\bar{c}$	Wing plan form	Wing-tip shape	Tail	TDPF	Initial rudder setting, with the spin (deg)	Method employed in recovery attempt	Data presented in-
23	2'	-120×10^{-4}	0.40	Rectangular	Round	1a	50×10^{-6}	15	Rudder reversal Rudder neutralization	Chart 23
24	2'	-120	.40	----do-----	-do--	1e	600	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 24 and table V
25	2'	-120	.40	----do-----	-do--	1e	600	15	Rudder reversal	Chart 25
26	1	0	.25	----do-----	-do--	2a	50	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 26 and table V
27	1	0	.25	----do-----	-do--	2a	50	15	Rudder reversal Rudder neutralization	Chart 27
28	1'	0	.40	----do-----	-do--	2a	50	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 28 and table V
29	1'	0	.40	----do-----	-do--	2a	50	15	Rudder reversal Rudder neutralization	Chart 29
30	2	-120	.25	----do-----	-do--	2a	50	30	Rudder reversal	Chart 30
31	2	-120	.25	----do-----	-do--	2a	50	15	-----------do-----------	Chart 31
32	1'	0	.40	----do-----	-do--	2e	600	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 32 and table V
33	1'	0	.40	----do-----	-do--	2e	600	15	Rudder reversal Rudder neutralization	Chart 33
34	2	-120	.25	----do-----	-do--	2e	600	30	Rudder reversal	Chart 34
35	2	-120	.25	----do-----	-do--	2e	600	15	Rudder reversal	Chart 35
36	1'	0	.40	----do-----	-do--	3a	50	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 36 and table V
37	1'	0	.40	----do-----	-do--	3a	50	15	Rudder reversal Rudder neutralization	Chart 37
38	2	-120	.25	----do-----	-do--	3a	50	30	Rudder reversal	Chart 38
39	2	-120	.25	----do-----	-do--	3a	50	15	-----------do-----------	Chart 39
40	1'	0	.40	----do-----	-do--	3e	600	30	Rudder reversal Rudder neutralization	Chart 40
41	1'	0	.40	----do-----	-do--	3e	600	15	Rudder reversal Rudder neutralization	Chart 41
42	2	-120	.25	----do-----	-do--	3e	600	30	Rudder reversal	Chart 42
43	2	-120	.25	----do-----	-do--	3e	600	15	-----------do-----------	Chart 43
44	1	0	.25	----do-----	-do--	4a	50	30	-----------do-----------	Chart 44
45	1	0	.25	----do-----	-do--	4a	50	15	-----------do-----------	Chart 45
46	1'	0	.40	----do-----	-do--	4a	50	30	Rudder reversal Rudder neutralization Simultaneous rudder and elevator neutralization	Chart 46 and table V
47	1'	0	.40	----do-----	-do--	4a	50	15	Rudder reversal Rudder neutralization	Chart 47
48	2	-120	.25	----do-----	-do--	4a	50	30	Rudder reversal	Chart 48

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TABLE III.- CONDITIONS TESTED ON THE MODEL - Concluded

Test condition	Loading	$\frac{I_X - I_Y}{mb^2}$	Center-of-gravity position, $x/\bar{c}$	Wing plan form	Wing-tip shape	Tail	TDPF	Initial rudder setting, with the spin (deg)	Method employed in recovery attempt	Data presented in -
49	2	-120×10^{-4}	0.25	Rectangular	Round	4a	50×10^{-6}	15	Rudder reversal Simultaneous rudder and elevator neutralization Simultaneous rudder and elevator reversal	Chart 49 and table V
50	2	-120	.25	----do----	--do--	4c	200	30	Rudder reversal	Chart 50
51	2	-120	.25	----do----	--do--	4c	200	15	----------do----------	Chart 51
52	2	-120	.25	----do----	--do--	4d	300	30	----------do----------	Chart 52
53	2	-120	.25	----do----	--do--	4d	300	15	----------do----------	Chart 53
54	2	-120	.25	----do----	--do--	4e	600	30	Rudder reversal Simultaneous rudder and aileron movement	Chart 54
55	2	-120	.25	----do----	--do--	4e	600	15	Rudder reversal	Chart 55
56	1'	0	.40	----do----	--do--	4e	600	30	Rudder reversal Rudder neutralization	Chart 56
57	1'	0	.40	----do----	--do--	4e	600	15	Rudder reversal Rudder neutralization	Chart 57
58	1'	0	.40	----do----	--do--	5a	50	30	Rudder reversal Rudder neutralization	Chart 58
59	1'	0	.40	----do----	--do--	5a	50	15	Rudder reversal Rudder neutralization	Chart 59
60	2	-120	.25	----do----	--do--	5a	50	30	Rudder reversal	Chart 60
61	2	-120	.25	----do----	--do--	5a	50	15	----------do----------	Chart 61
62	2	-120	.25	----do----	--do--	5b	100	30	----------do----------	Chart 62
63	2	-120	.25	----do----	--do--	5b	100	15	----------do----------	Chart 63
64	1'	0	.40	----do----	Square	1a	50	30	----------do----------	Chart 64
65	2	-120	.25	----do----	--do--	1a	50	30	----------do----------	Chart 7
66	1'	0	.40	Tapered	Round	1a	50	30	----------do----------	Chart 65
67	1'	0	.40	----do----	--do--	1a	50	15	----------do----------	Chart 66
68	2	-120	.25	----do----	--do--	1a	50	30	----------do----------	Chart 67
69	2	-120	.25	----do----	--do--	1a	50	15	----------do----------	Chart 68
70	2	-120	.25	----do----	--do--	4c	200	30	----------do----------	Chart 50
71	2	-120	.25	----do----	--do--	4c	200	15	----------do----------	Chart 51
72	2	-120	.25	----do----	--do--	4d	300	30	----------do----------	Chart 52
73	2	-120	.25	----do----	--do--	4d	300	15	----------do----------	Chart 53
74	1'	0	.40	----do----	Square	1a	50	30	----------do----------	Chart 69
75	2	-120	.25	----do----	--do--	1a	50	30	----------do----------	Chart 67
76	2	-120	.25	----do----	--do--	1a	50	15	----------do----------	Chart 68
77	1	0	.25	Rectangular	Round	1c	200	30	Simultaneous rudder and elevator neutralization	Table V
78	1'	0	.40	----do----	--do--	1b	100	30	----------do----------	Table V
79	1'	0	.40	----do----	--do--	1d	300	30	----------do----------	Table V
80	1'	0	.40	----do----	--do--	2c	200	30	----------do----------	Table V
81	1	0	.25	----do----	--do--	3a	50	30	----------do----------	Table V
82	1	0	.25	----do----	--do--	3e	600	30	----------do----------	Table V
83	1'	0	.40	----do----	--do--	3x	0	30	----------do----------	Table V

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TABLE IV.- MASS CHARACTERISTICS AND INERTIA PARAMETERS

FOR LOADINGS TESTED ON THE MODEL

[Model values converted to corresponding full-scale values; moments of inertia given about center of gravity]

Loading	Weight (lb)	Center-of-gravity location		μ		Moments of inertia			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	5000 feet	I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1 1'	2180	0.25 .40	0.09	5.21	6.04	1498	1498	2908	0×10^{-4}	-184×10^{-4}	184×10^{-4}
2 2'	2180	.25 .40	.09	5.21	6.04	1080	2000	3055	-120	-138	258

TABLE V.- THE INFLUENCE OF VARIOUS TAIL CONFIGURATIONS IN EFFECTING RECOVERY BY SIMULTANEOUS NEUTRALIZATION OF RUDDER AND ELEVATOR

[Loading and center-of-gravity position as indicated]

Tail description	Tail	TDPF	Loading	$x/\bar{c}$	$\frac{I_X - I_Y}{mb^2}$	Initial rudder setting (deg)	Aileron setting (deg)	Initial elevator setting (deg)	Full-scale vertical velocity (ft/sec)	Turns for recovery
Normal tail	1a	50×10^{-6}	1	0.25	0×10^{-4}	30W	Neutral	30U	142	$\frac{3}{4}$, $\frac{3}{4}$
							Neutral	20U	139	1, $1\frac{1}{4}$
							7W	30U	124	1, $1\frac{1}{4}$
							7W	20U	125	$1\frac{3}{4}$, 2
	1c	200	1	.25	0	30W	Neutral	30U	139	1, 1
							Neutral	20U	135	1, 1
							7W	30U	135	1, $1\frac{1}{2}$
							7W	20U	130	$1\frac{1}{2}$, $1\frac{1}{2}$
	1e	600	1	.25	0	30W	Neutral	30U	144	$\frac{1}{2}$, $\frac{1}{2}$
							Neutral	20U	157	1, $1\frac{1}{4}$
							7W	30U	135 to 144	$\frac{3}{4}$, $\frac{3}{4}$
							7W	20U	139	$1\frac{1}{4}$, $1\frac{1}{4}$
Large vertical tail	2a	50	1	.25	0	30W	Neutral	30U	139	$\frac{1}{2}$, $\frac{1}{2}$
							Neutral	20U	144	$\frac{1}{2}$, $\frac{3}{4}$
							7W	30U	125	$\frac{1}{2}$, 1
							7W	20U	125	$\frac{3}{4}$, $1\frac{1}{4}$
Partial-length rudder	3a	50	1	.25	0	30W	Neutral	30U	154	$\frac{1}{2}$, $\frac{3}{4}$
							Neutral	20U	154	1, $1\frac{1}{4}$
							7W	30U	144	1, 1
							7W	20U	144	$1\frac{1}{4}$, $1\frac{1}{2}$
	3e	600	1	.25	0	30W	Neutral	30U	154	$\frac{3}{4}$, 1
							Neutral	20U	154	$\frac{3}{4}$, 1
							7W	30U	139	$\frac{3}{4}$, 1
							7W	20U	154	2, 2
Normal tail	1a	50	2	.25	-120	30W	Neutral	30U	139	1, $1\frac{1}{4}$
							Neutral	20U	137	1, $1\frac{1}{4}$
							7W	30U	135	1, $1\frac{1}{2}$
							7W	20U	142	1, $1\frac{1}{2}$
							7A	30U	149	$\frac{1}{4}$, $\frac{1}{2}$
							7A	20U	130	$\frac{3}{4}$, 1
	1e	600	2	.25	-120	30W	Neutral	30U	144	$\frac{3}{4}$, $1\frac{1}{4}$
							Neutral	20U	144	$1\frac{1}{4}$, $1\frac{1}{4}$
							7W	30U	126	$1\frac{1}{4}$, $1\frac{1}{4}$
							7W	20U	139	$1\frac{1}{2}$, $1\frac{3}{4}$
Large horizontal tail	4a	50	2	.25	-120	15W	Neutral	30U	174	$\frac{1}{2}$, $\frac{1}{2}$
							20A	30U	146	$\frac{1}{2}$, $\frac{3}{4}$
							20W	30U	> 164	$\frac{3}{4}$, $\frac{3}{4}$
							7A	20U	169	$1\frac{1}{4}$, $1\frac{1}{4}$

W with the spin; A against the spin; U up; D down

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TABLE V.- THE INFLUENCE OF VARIOUS TAIL CONFIGURATIONS IN EFFECTING RECOVERY BY SIMULTANEOUS NEUTRALIZATION OF RUDDER AND ELEVATOR - Concluded

Tail description	Tail	TDPF	Loading	$x/\bar{c}$	$\frac{I_X - I_Y}{mb^2}$	Initial rudder setting (deg)	Aileron setting (deg)	Initial elevator setting (deg)	Full-scale vertical velocity (ft/sec)	Turns for recovery
Normal tail	1a	50×10^{-6}	1'	0.40	0×10^{-4}	30W	Neutral	30U	122 to 143	$\frac{1}{2}$, $\frac{3}{4}$
							Neutral	20U	129	1, 1
							7W	30U	116	$1\frac{1}{4}$, $1\frac{1}{2}$
							7W	20U	139	$1\frac{1}{4}$, $1\frac{1}{2}$
	1b	100	1'	.40	0	30W	Neutral	30U	135	$\frac{3}{4}$, $1\frac{1}{2}$
							Neutral	20U	125 to 139	> 3
							7W	30U	121	1, > $2\frac{1}{2}$
							7W	20U	139	>4
	1d	300	1'	.40	0	30W	Neutral	30U	135	> 6
							7W	30U	116	> 3
	1e	600	1'	.40	0	30W	Neutral	30U	123 to 136	> 8
							7W	30U	126	∞
Large vertical tail	2a	50	1'	.40	0	30W	Neutral	30U	123	$1\frac{3}{4}$, $1\frac{3}{4}$
							Neutral	20U	94	3, $3\frac{1}{2}$
							7W	30U	111	1
							7W	20U	101	$2\frac{3}{4}$, 3
	2c	200	1'	.40	0	30W	Neutral	30U	101	$\frac{1}{2}$, $2\frac{1}{2}$
							Neutral	20U	96	2, 3
							7W	30U	111	$\frac{3}{4}$, $1\frac{1}{4}$
							7W	20U	96	2, 3
	2e	600	1'	.40	0	30W	Neutral	30U	108	$\frac{1}{2}$, $\frac{1}{2}$
							Neutral	20U	111 to 139	$\frac{3}{4}$, 1
							7W	30U	106	> $2\frac{1}{2}$
							7W	20U	111	>3
Partial-length rudder	3a	50	1'	.40	0	30W	Neutral	30U	139	$\frac{1}{4}$, $\frac{1}{4}$
							Neutral	20U	154	$\frac{1}{2}$, > 4
							7W	30U	139	> $2\frac{1}{2}$
							7W	20U	154	> 4
	3x	0	1'	.40	0	30W	Neutral	30U	139	$\frac{1}{4}$, $\frac{1}{2}$
							Neutral	20U	139	$\frac{3}{4}$, 1
							7W	30U	139	$\frac{1}{2}$, $\frac{3}{4}$
							7W	20U	139	$\frac{3}{4}$, $1\frac{1}{2}$
Large horizontal tail	4a	50	1'	.40	0	30W	Neutral	30U	131 to 146	$\frac{3}{4}$, $\frac{3}{4}$
							Neutral	20U	147	$\frac{3}{4}$, 1
							7W	30U	139	1, 1
							7W	20U	144	1, $1\frac{1}{4}$
Normal tail	1a	50	2'	.40	-120	30W	Neutral	30U	139	$\frac{1}{4}$, $\frac{1}{2}$
							Neutral	20U	125 to 137	$\frac{1}{2}$, 1
							7W	30U	125	$\frac{1}{4}$, $\frac{1}{2}$
							7W	20U	139	1, $1\frac{1}{2}$
							7A	30U	139	$\frac{1}{4}$, $\frac{1}{4}$
							7A	20U	132	$\frac{1}{2}$, 1
	1e	600	2'	.40	-120	30W	Neutral	30U	116	> 3
							Neutral	20U	135	> 2
							7W	30U	106	> $2\frac{3}{4}$

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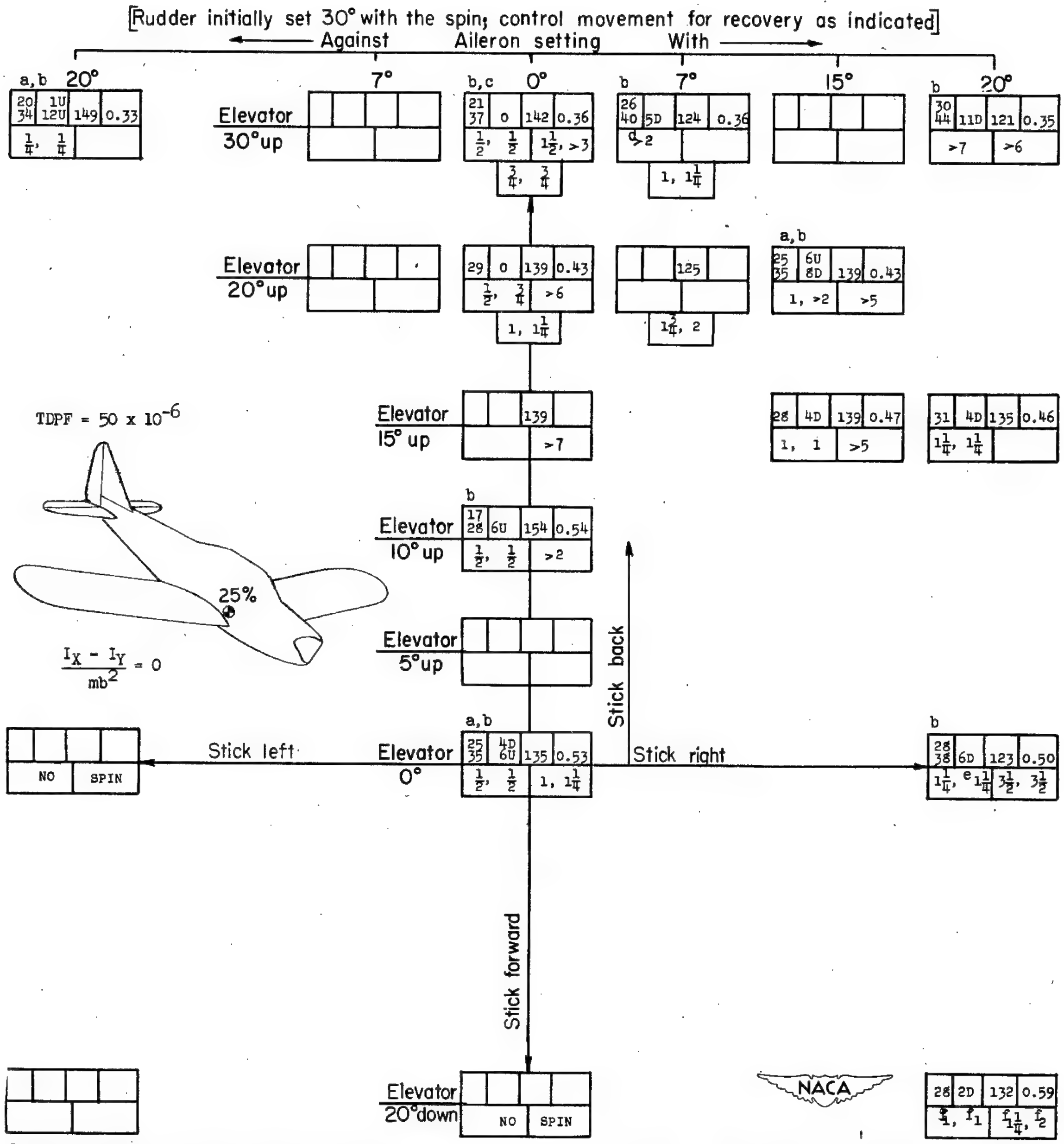
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 1 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



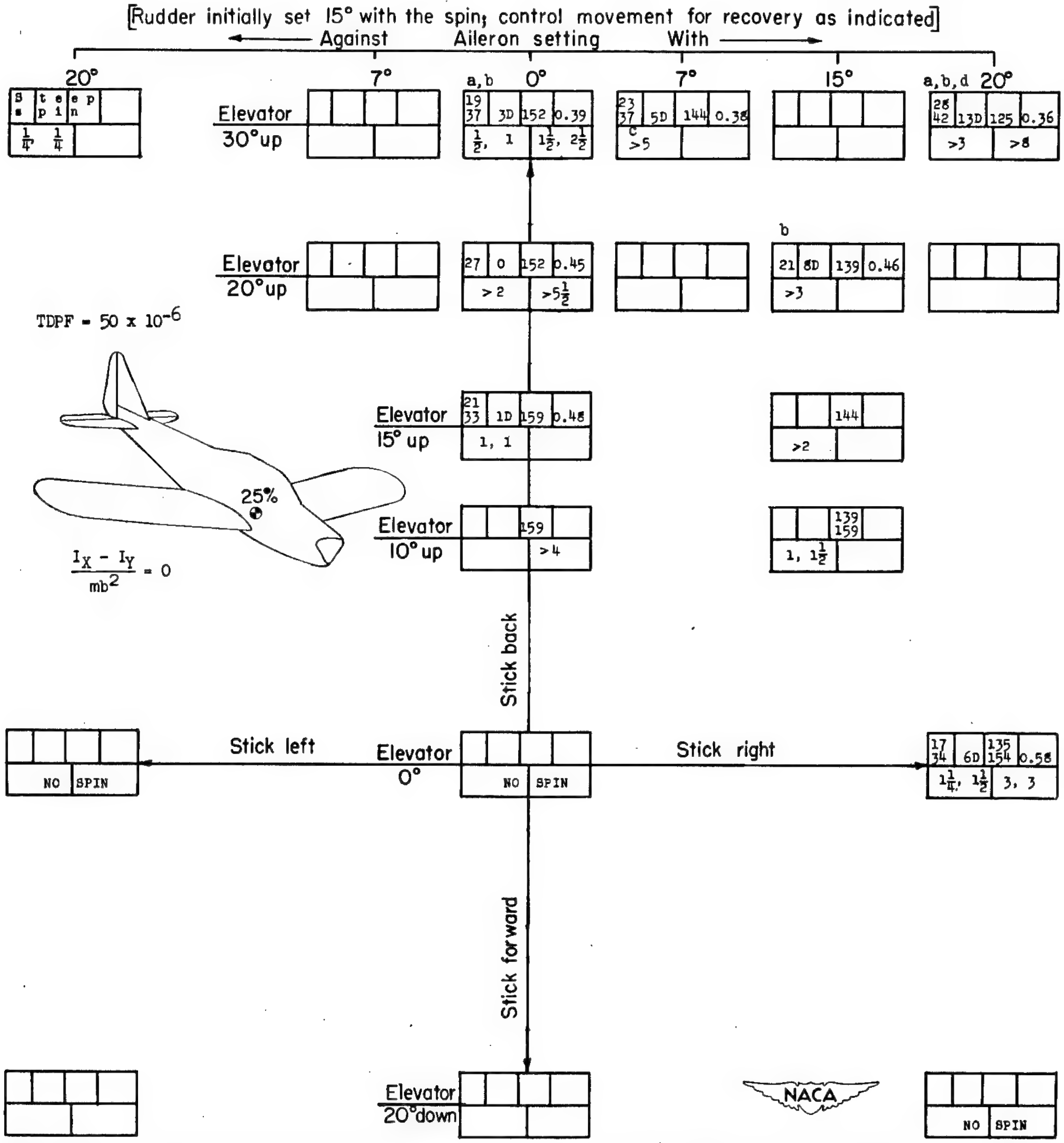
[a]Oscillatory in roll and yaw; range or average values given.
[b]Oscillatory in pitch; range or average values given.
[c]Wandering spin.
[d]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Visual estimate.
[f]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	
Turns for recovery: Rudder 30° with to 0°, Elevator neutralized.			

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 2 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



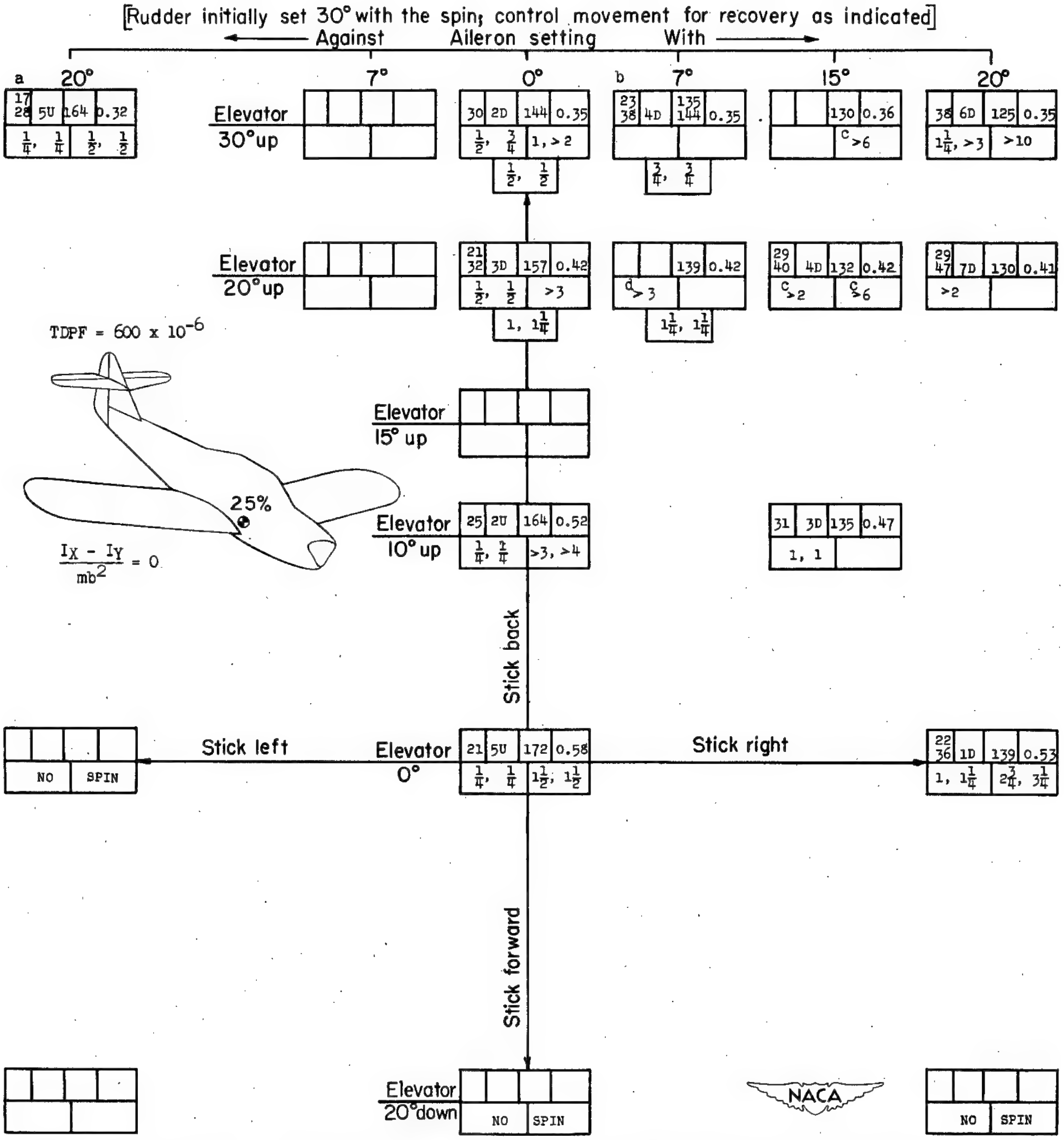
[a]Oscillatory in pitch; range or average values given.
[b]Wandering spin.
[c]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Whipping spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 3.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 3 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



aOscillates in pitch, roll, and yaw; range or average values given.
bOscillates in pitch; range of values given.
cVisual estimate.
dRudder reversed to only 20° (2/3 of its full deflection) against the spin.

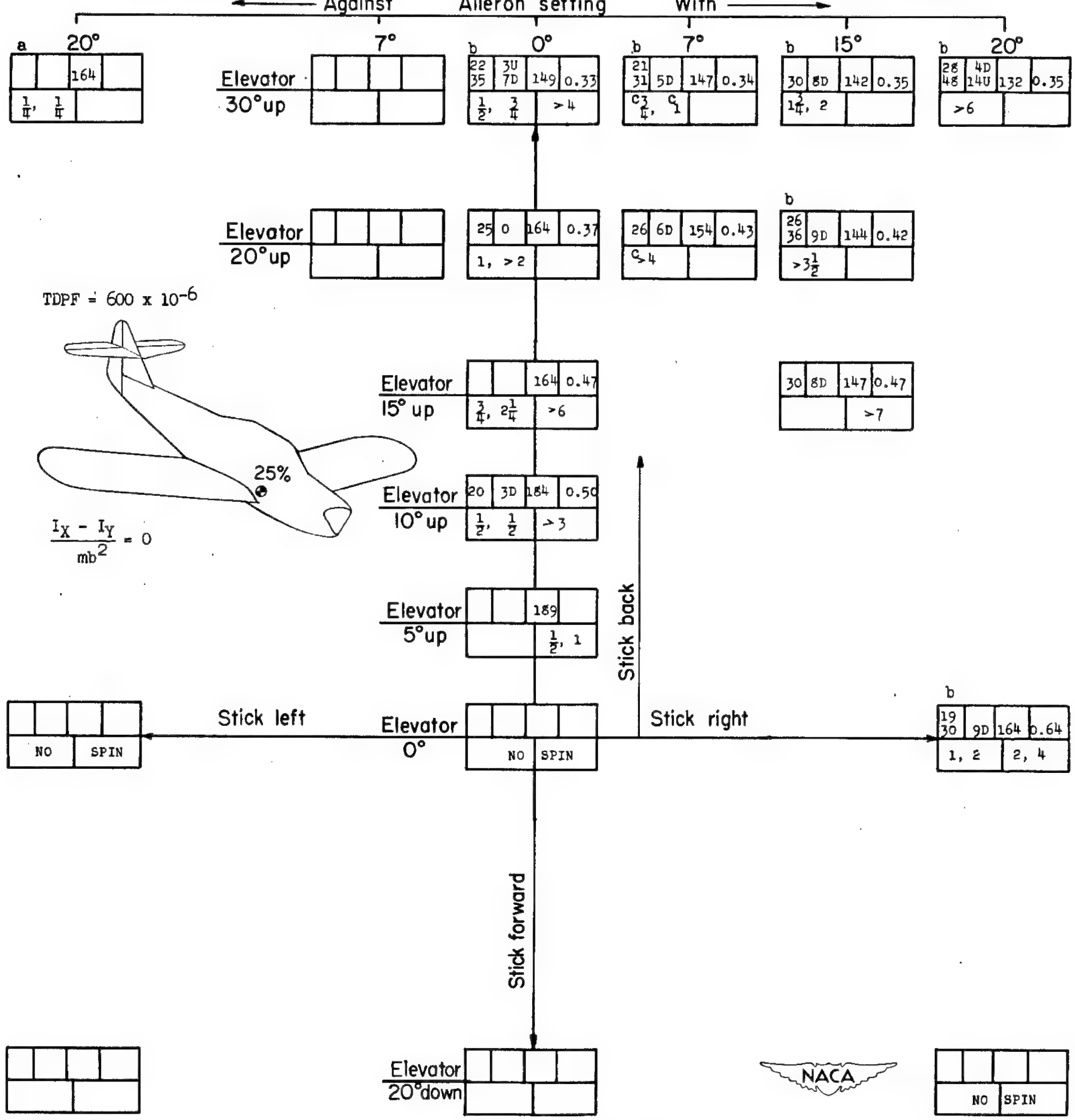
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

Turns for recovery: Rudder 30° with to 0°; Elevator neutralized.

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 4 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]

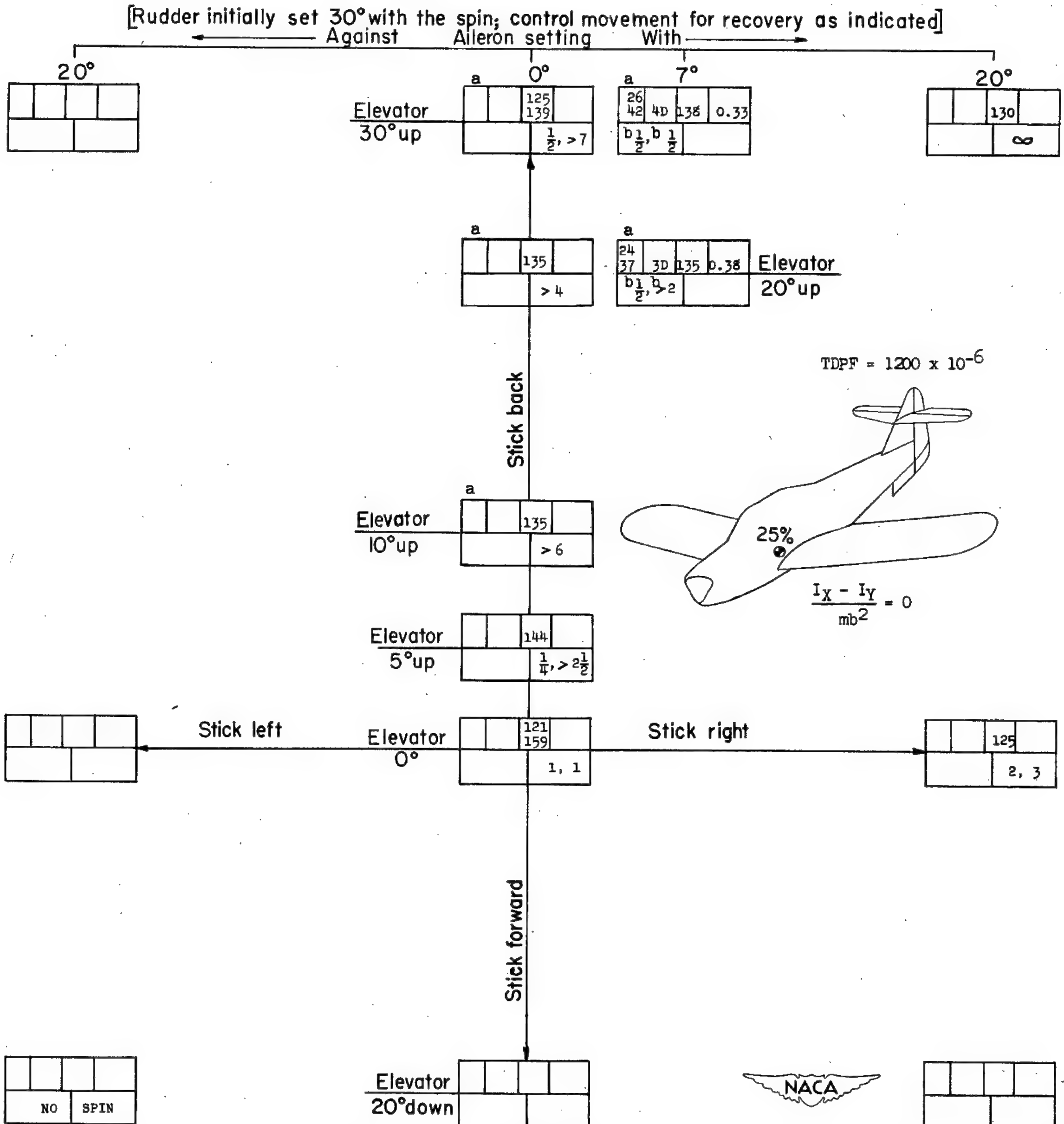


[a]Wide radius spin.
[b]Oscillatory primarily in pitch; range or average values given.
[c]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 5.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 5 LISTED IN TABLE III

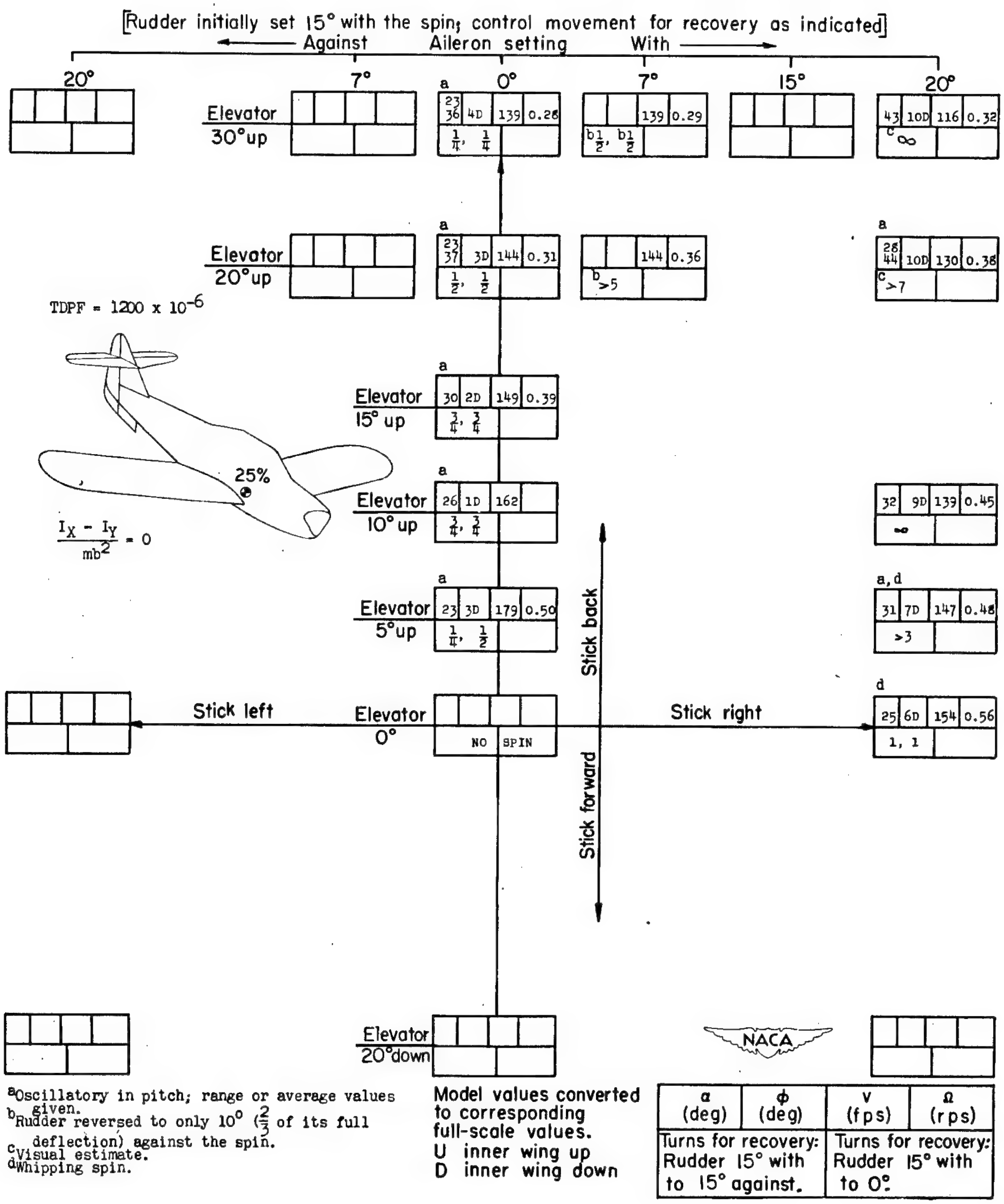


[a]Oscillatory in pitch; range or average values given.
[b]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 6.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 6 LISTED IN TABLE III

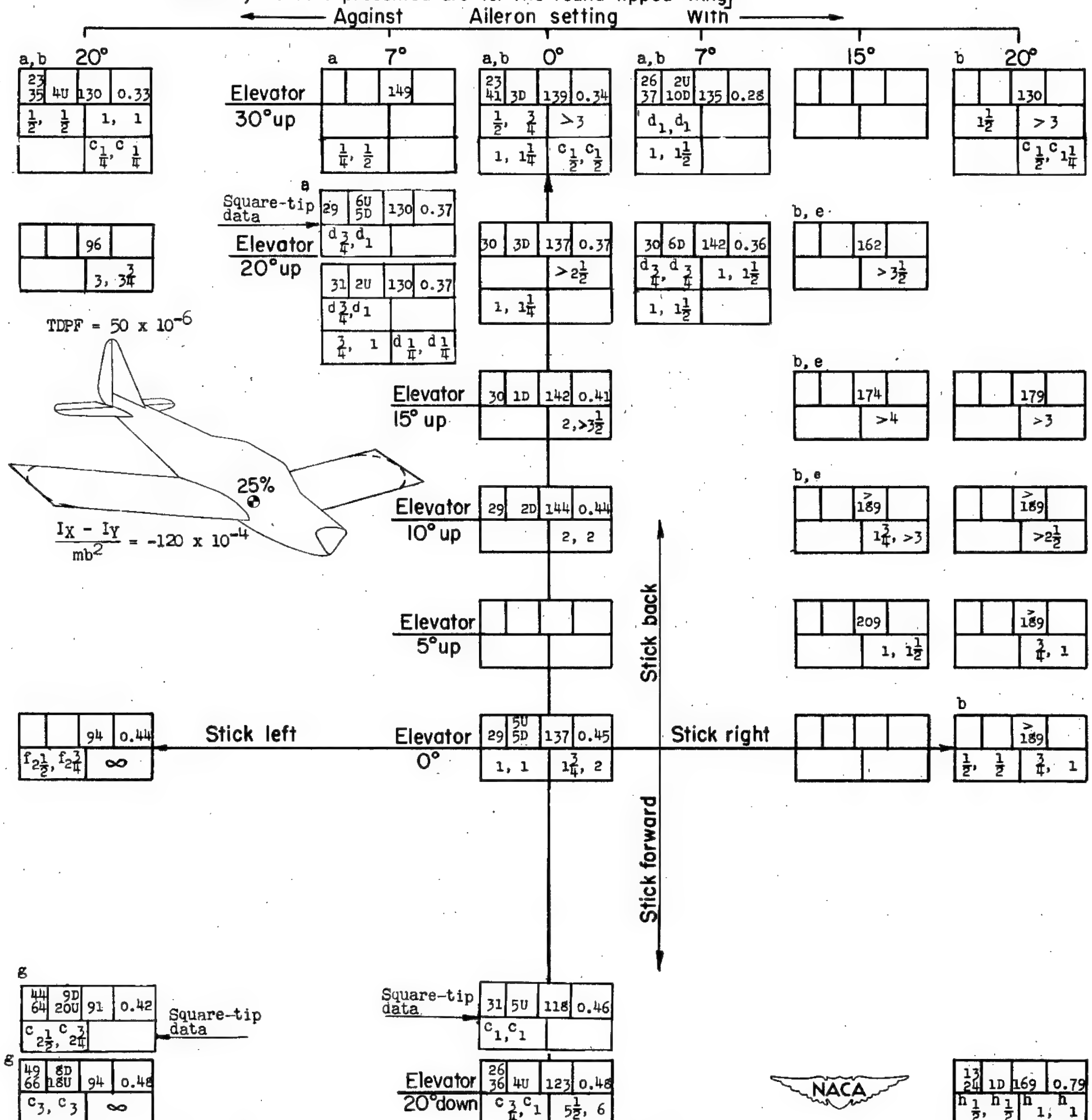


[a]Oscillatory in pitch; range or average values given.
[b]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Visual estimate.
[d]Whipping spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

CHART 7.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITIONS 7 AND 65 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated; unless otherwise indicated, the data presented are for the round-tipped wing]



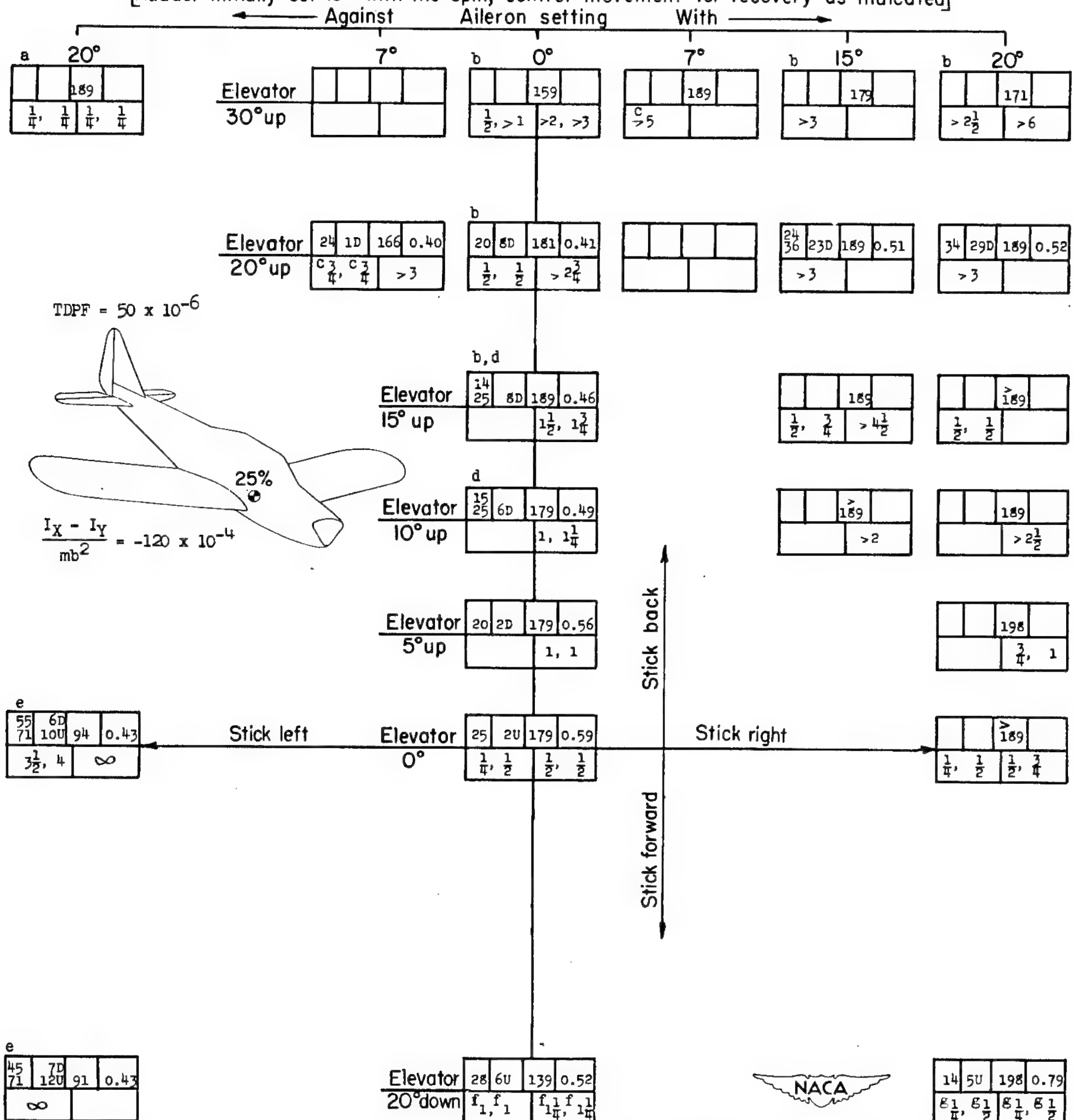
[a]Oscillatory in pitch; range or average values given.
[b]Wandering spin.
[c]Goes into an inverted glide.
[d]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection against the spin).
[e]Whipping spin.
[f]Goes into an inverted dive.
[g]Oscillatory in pitch, roll, and yaw; range or average values given.
[h]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	
Turns for recovery: Rudder 30° with to 0°, Elevator neutralized.		Turns for recovery: Rudder 30° with to 30° against, Elevator reversed to full down.	

CHART 8.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 8 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]

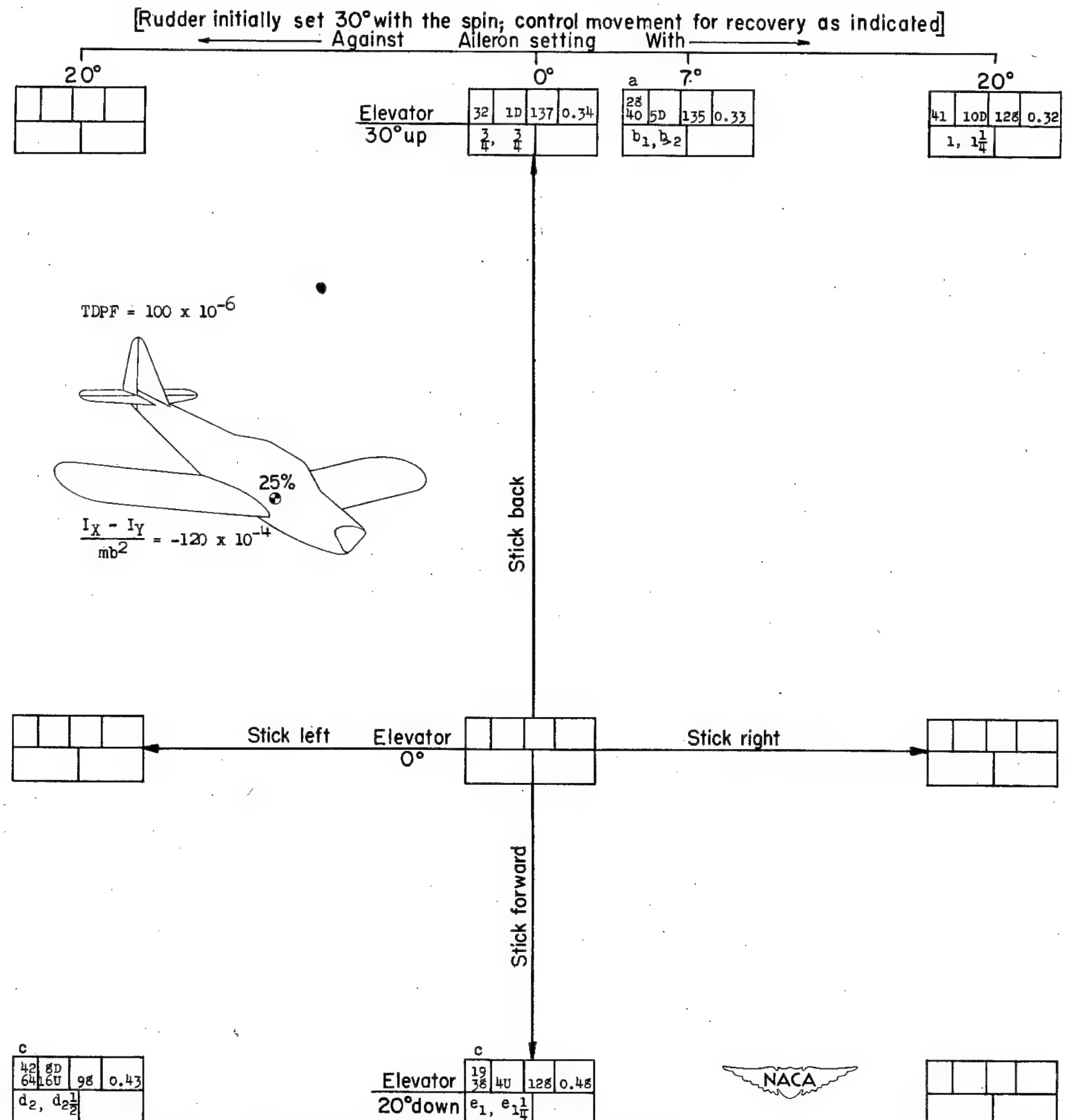


Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

[a] Wide radius spin, oscillatory in roll and yaw.
[b] Wandering spin.
[c] Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[d] Oscillatory in pitch; range or average values given.
[e] Oscillatory in pitch, roll, and yaw; range or average values given.
[f] Goes into an inverted glide.
[g] Goes into inverted spin after recovery from erect spin.

CHART 9.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 9 LISTED IN TABLE III



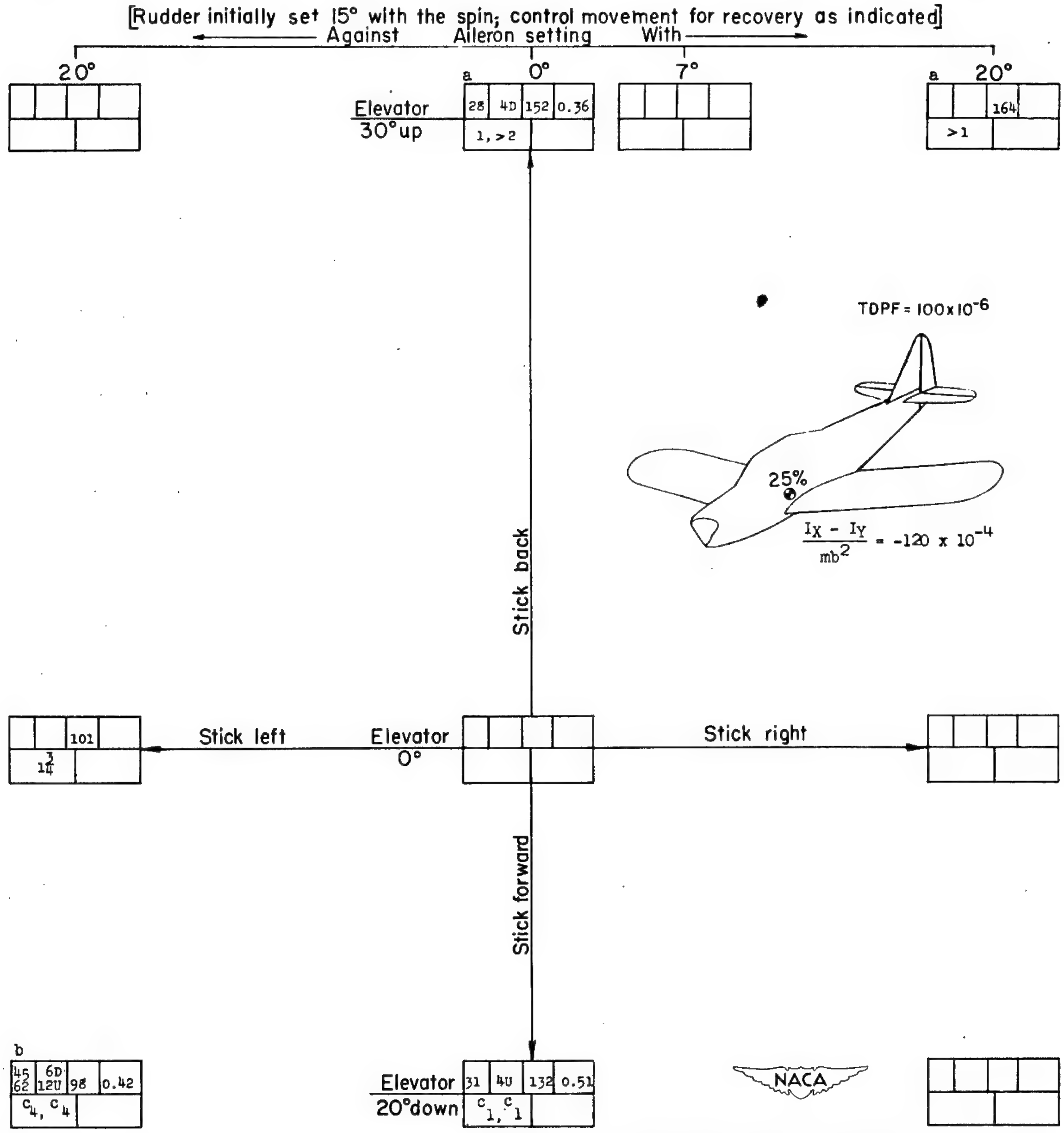
[a]Oscillatory in pitch; range or average values given.
[b]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Oscillatory in pitch, roll, and yaw; range or average values given.
[d]Goes inverted and then becomes erect and spins to left after recovery from right spin.
[e]Goes into an inverted dive.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 10.—SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 10 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



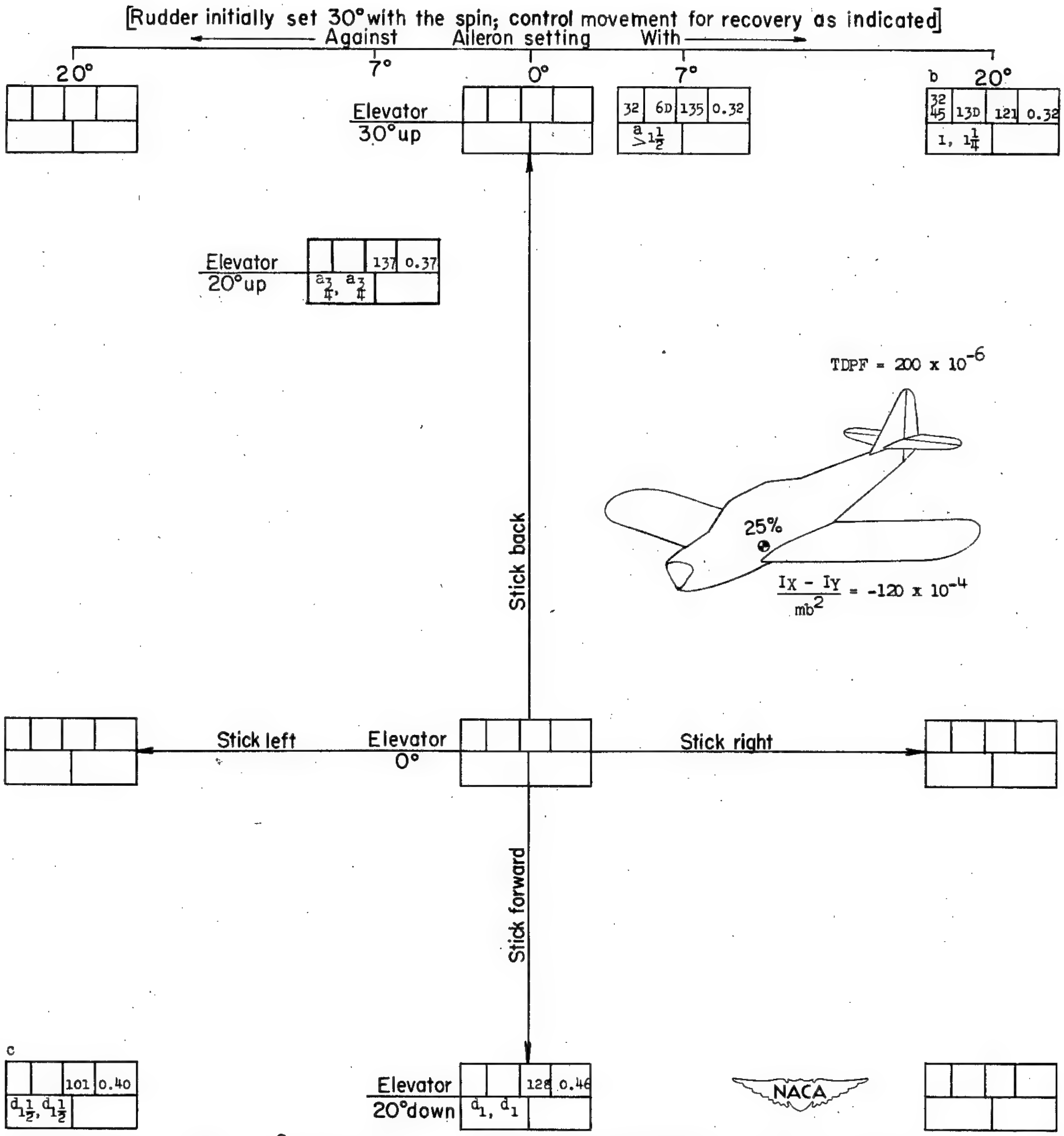
[a]Wandering spin.
[b]Oscillatory in pitch, roll, and yaw; range or average values given.
[c]Goes into an inverted dive.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART II.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION II LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]

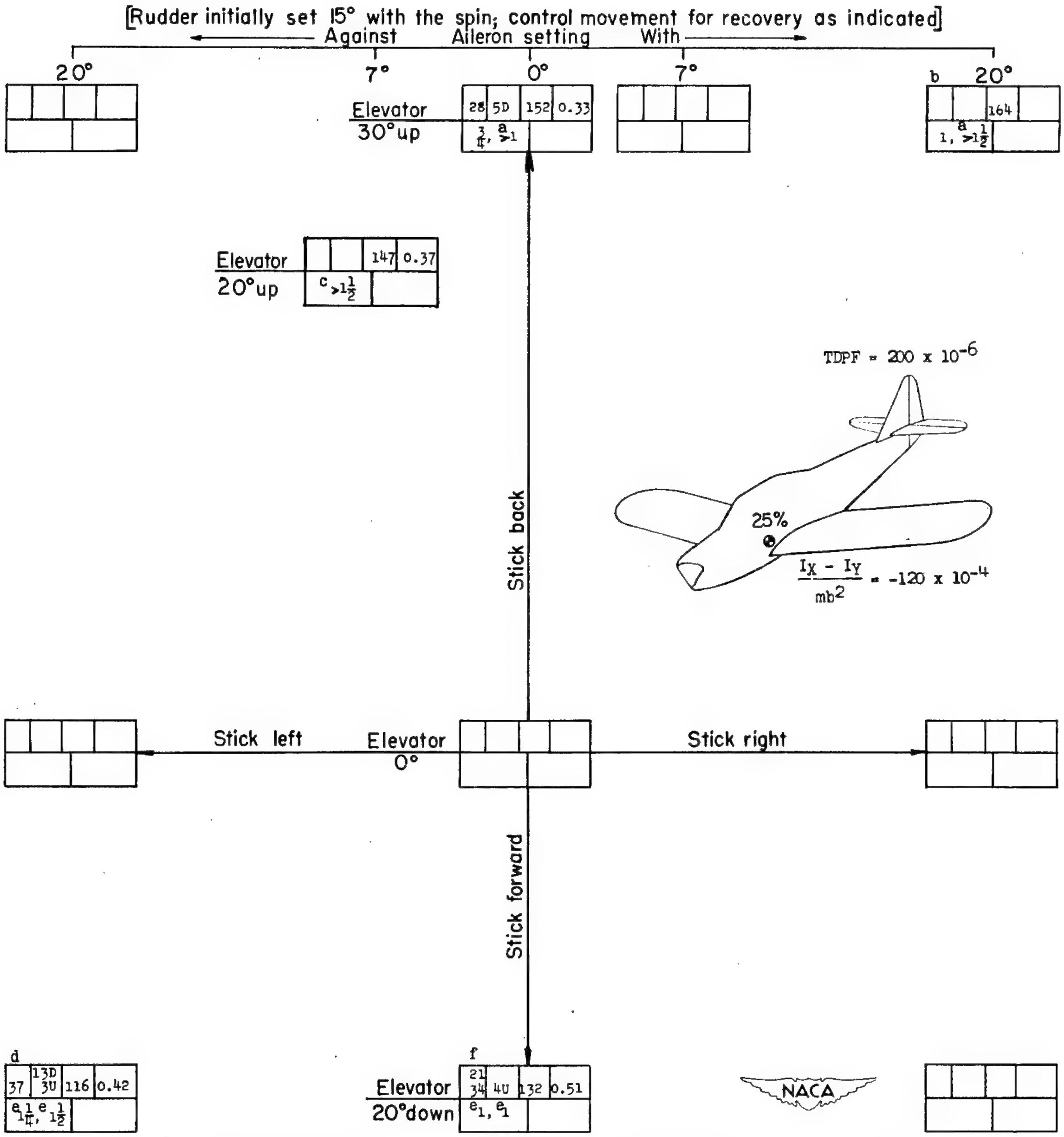


[a] Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[b] Oscillatory in pitch; range or average values given.
[c] Oscillatory in roll and yaw.
[d] Visual estimate.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 12.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 12 LISTED IN TABLE III

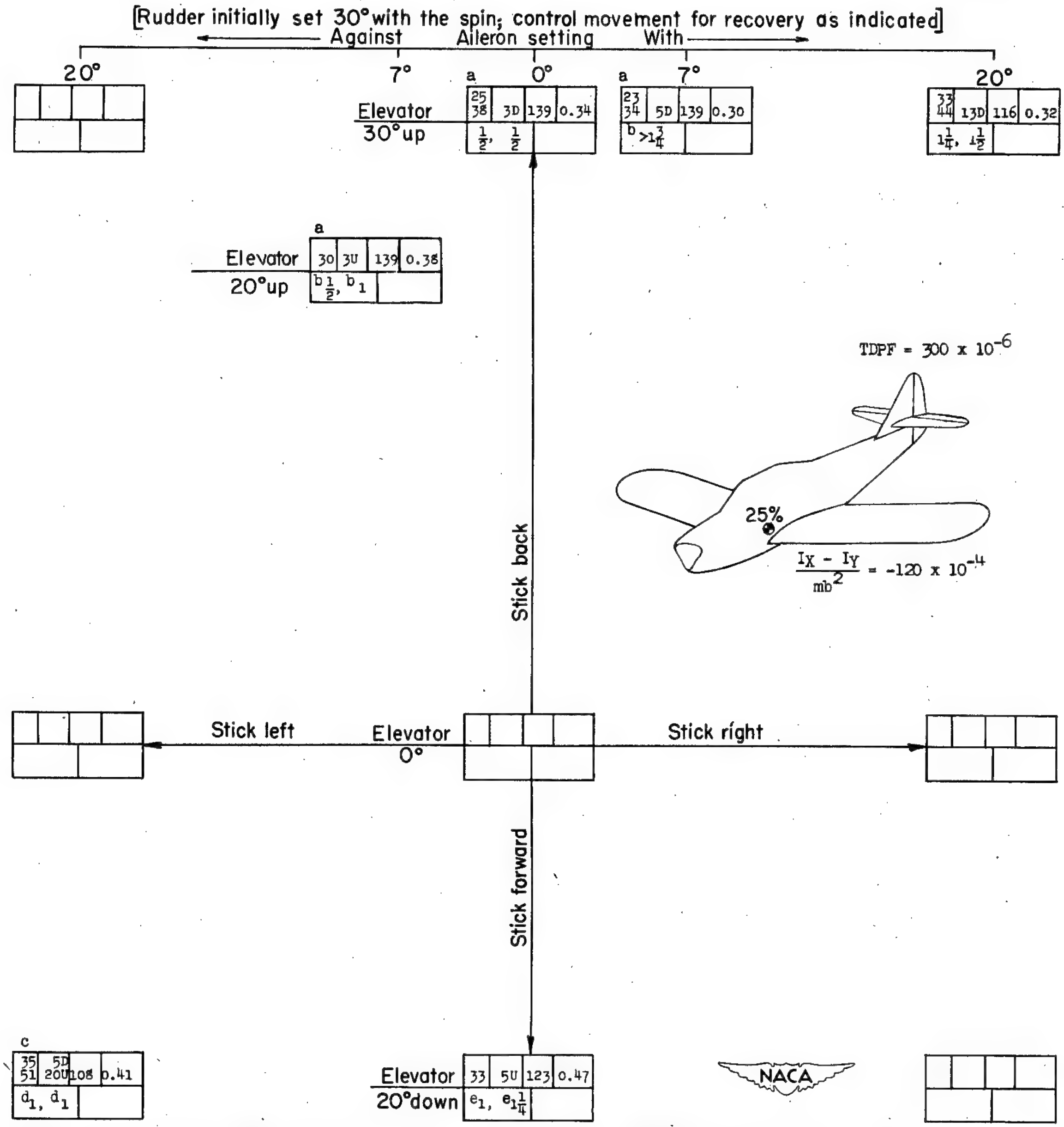


[a]Approximately $\frac{1}{2}$ to $\frac{3}{4}$ turn after rudder reversal model's attitude became very steep at which time the up elevator caused the model to pull up into a flatter attitude and continue turning to the right.
[b]Wandering spin.
[c]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Oscillatory in roll and yaw; range of values given.
[e]Goes into an inverted dive.
[f]Slightly oscillatory in pitch; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 13.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 13 LISTED IN TABLE III



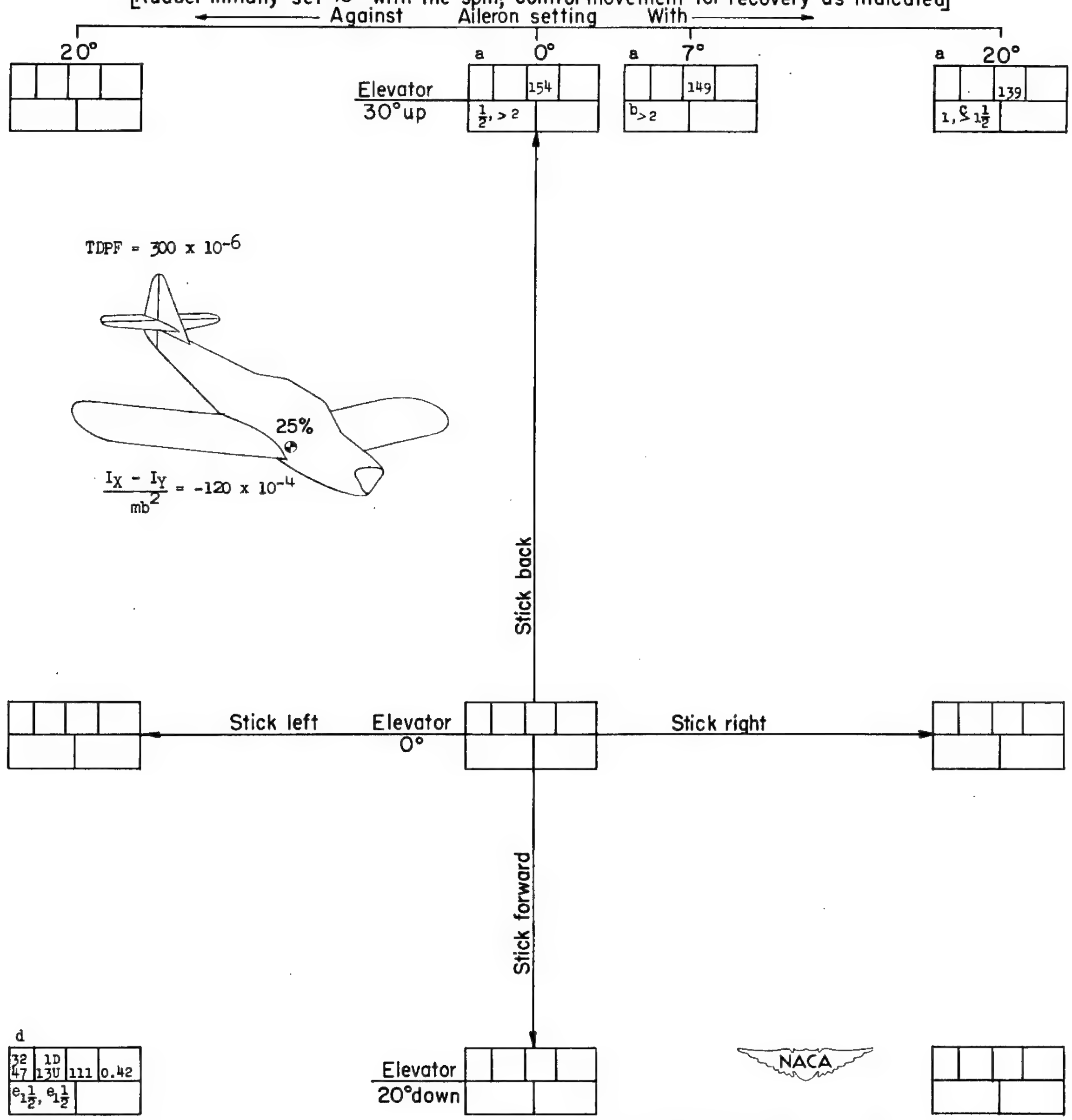
[a]Oscillatory in pitch; range or average values given.
[b]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Oscillatory in pitch, roll, and yaw; range or average values given.
[d]Goes inverted then begins spinning in an erect left spin after recovery from right spin.
[e]Goes into an inverted glide.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 14.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 14 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



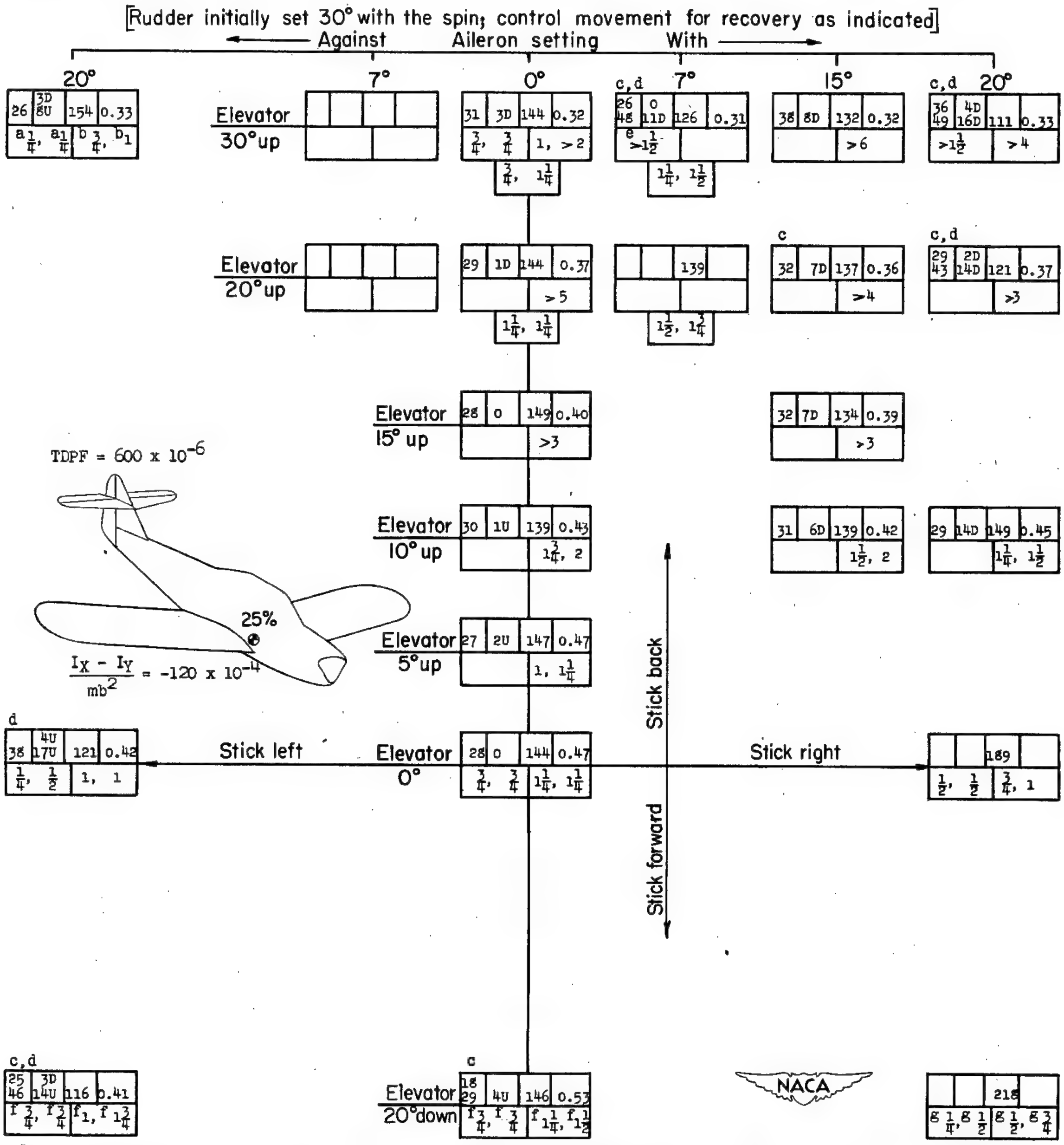
[a]Wandering spin.
[b]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Visual estimate.
[d]Oscillatory in pitch, roll, and yaw; range or average values given.
[e]Goes into an inverted glide.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 15.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 15 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



a Goes into a spin to the left after recovery from right spin.
b Goes into a slightly turning glide.
c Oscillatory in pitch; range or average values given.
d Oscillatory in roll and yaw; range or average values given.
e Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
f Goes into an inverted glide.
g Goes into an inverted spin after recovery from erect spin.

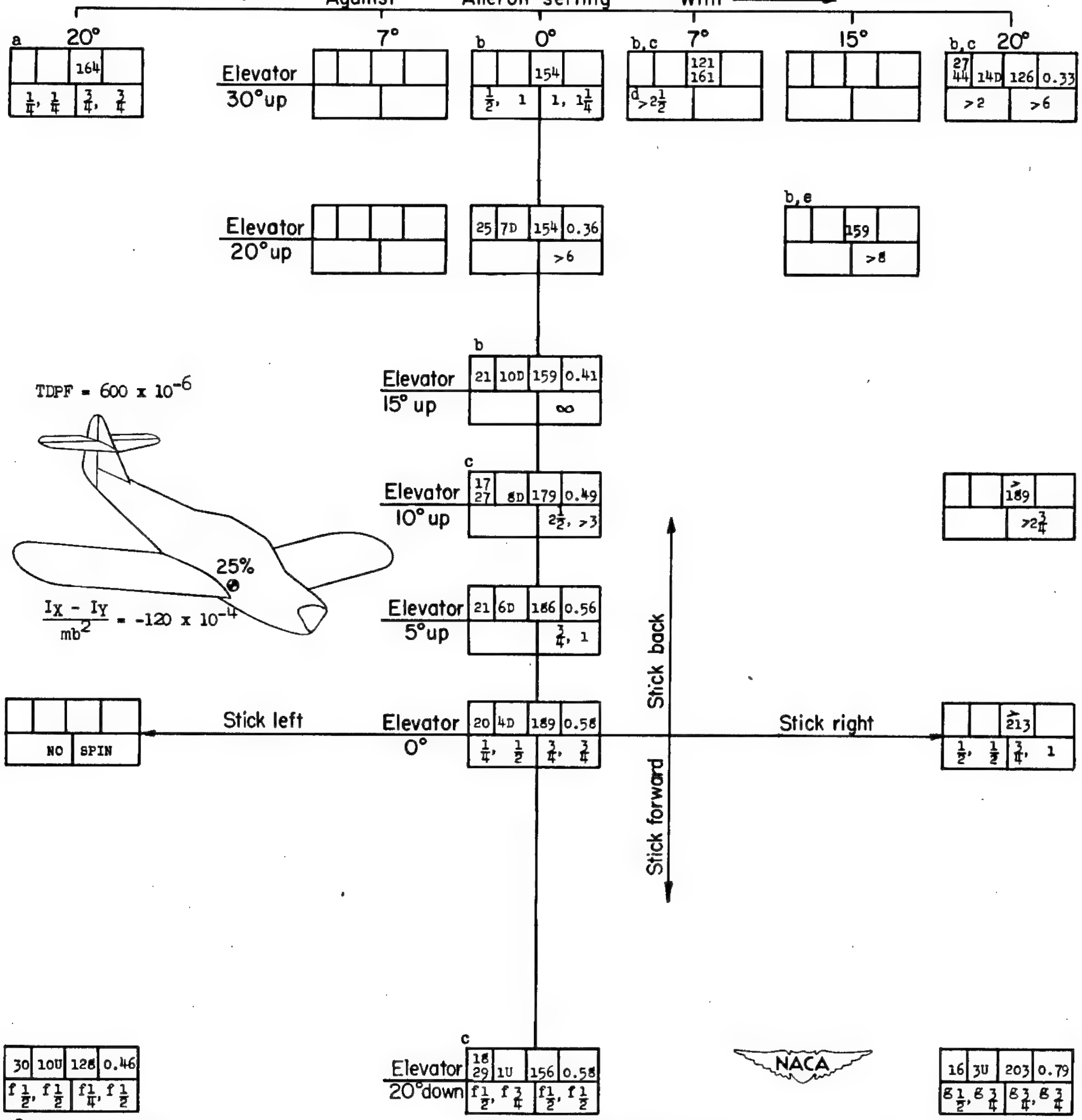
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

Turns for recovery: Rudder 30° with to 0°; Elevator neutralized.

CHART 16.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 16 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



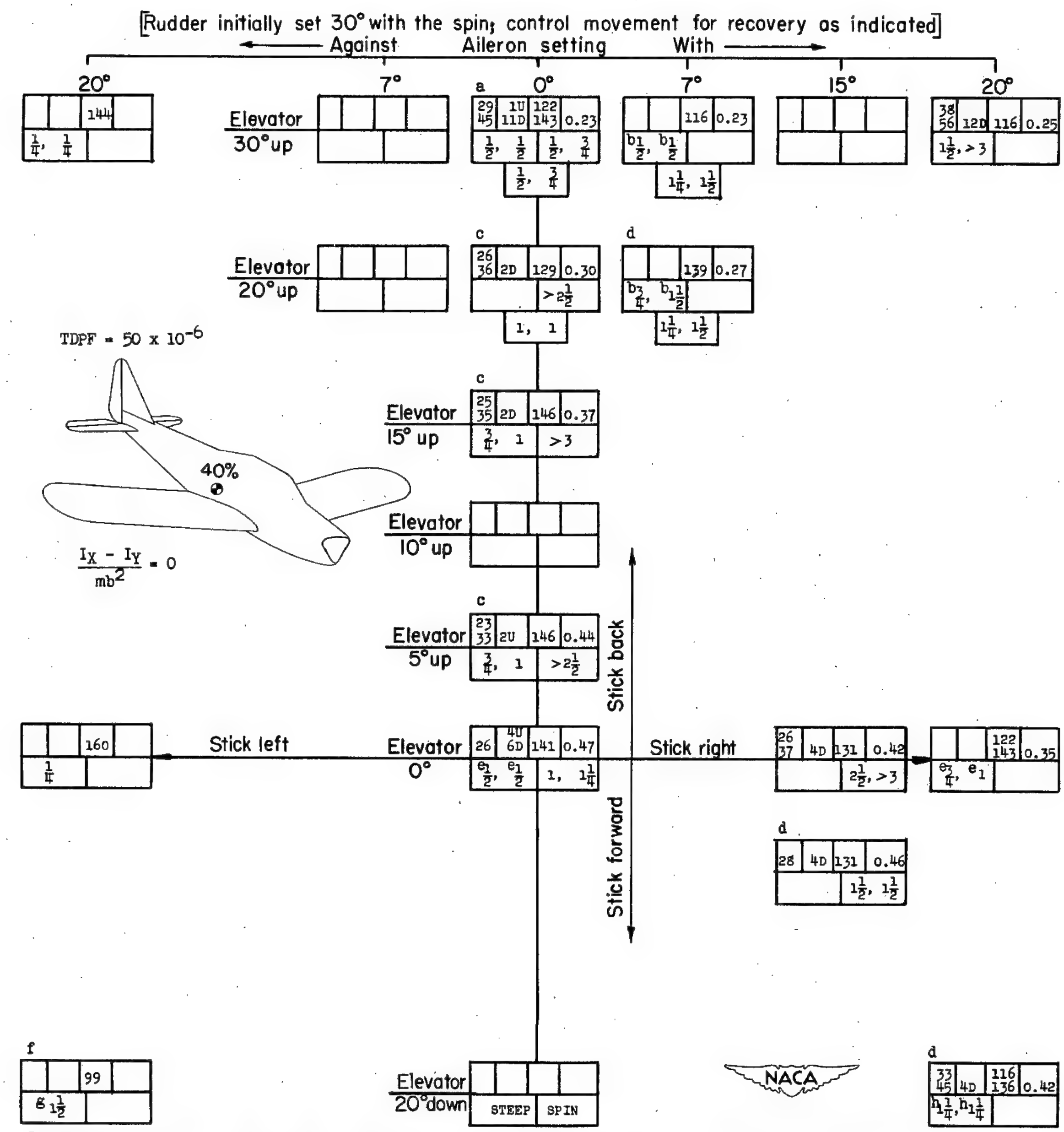
[a]Wide radius spin.
[b]Wandering spin.
[c]Oscillatory in pitch; range or average values given.
[d]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Whipping spin.
[f]Goes into an inverted dive.
[g]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 17.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 17 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]

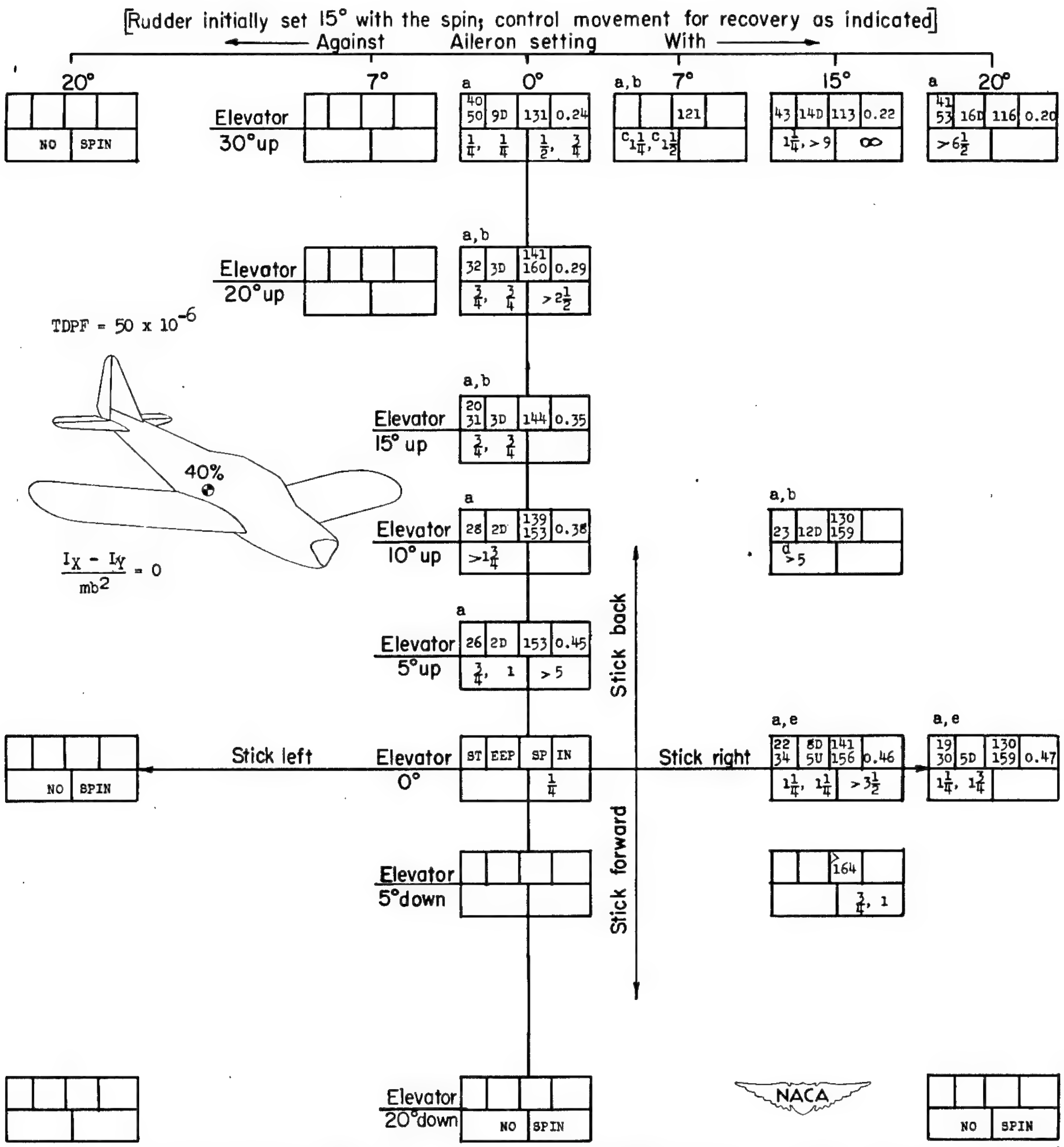


[a]Oscillates in pitch, roll, and yaw; range of values given.
[b]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Oscillatory in pitch; range of values given.
[d]Oscillatory in pitch and has a whipping motion.
[e]Visual estimate.
[f]A "no spin" condition also obtained.
[g]Goes into an inverted glide.
[h]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	
Turns for recovery: Rudder 30° with to 0°; Elevator neutralized.			

CHART 18.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 18 LISTED IN TABLE III



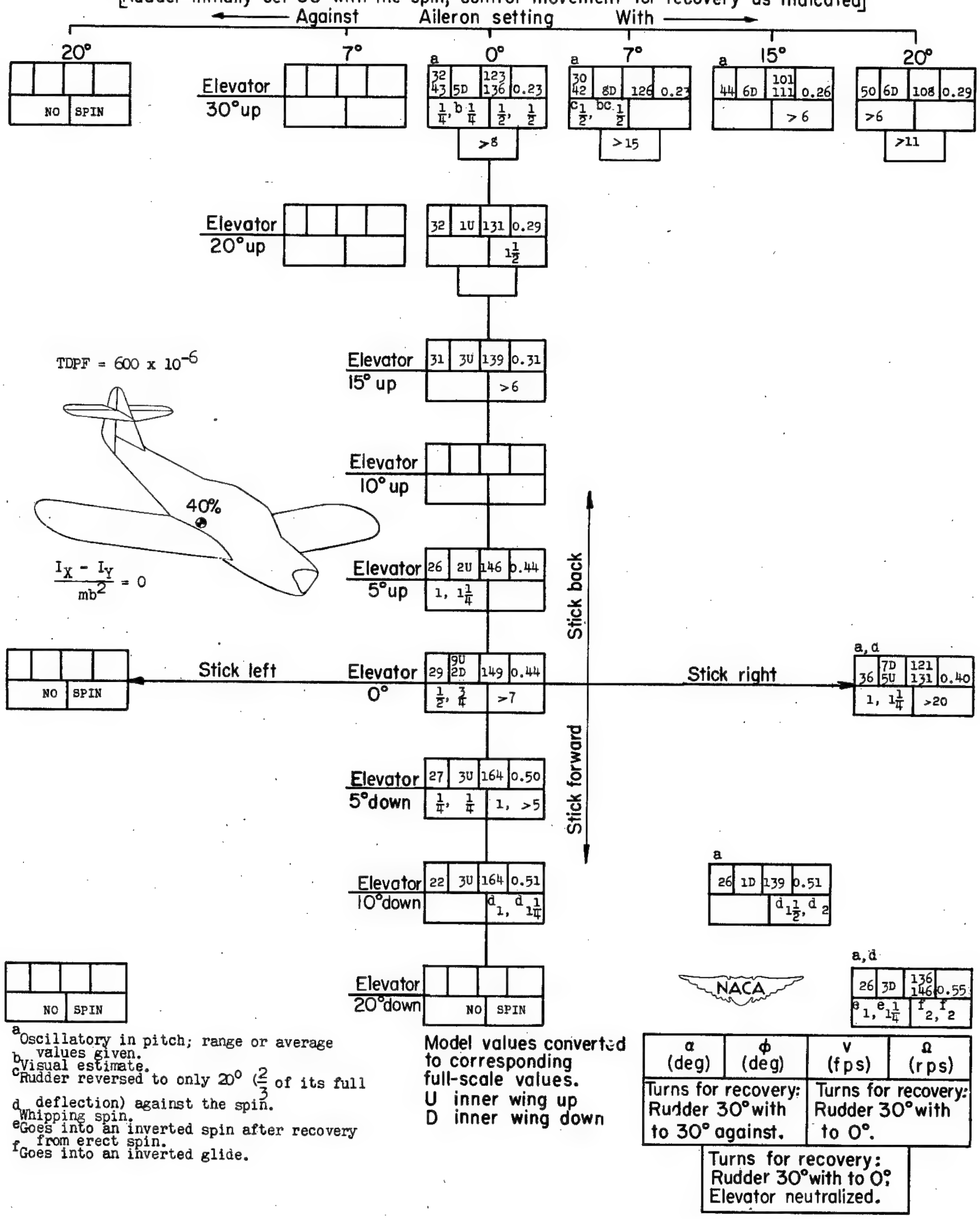
aOscillatory in pitch; range or average values given.
bWandering spin.
cRudder reversed to only 10° (2/3 of its full deflection) against the spin.
dVisual estimate.
eWhipping spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 19.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 19 LISTED IN TABLE III

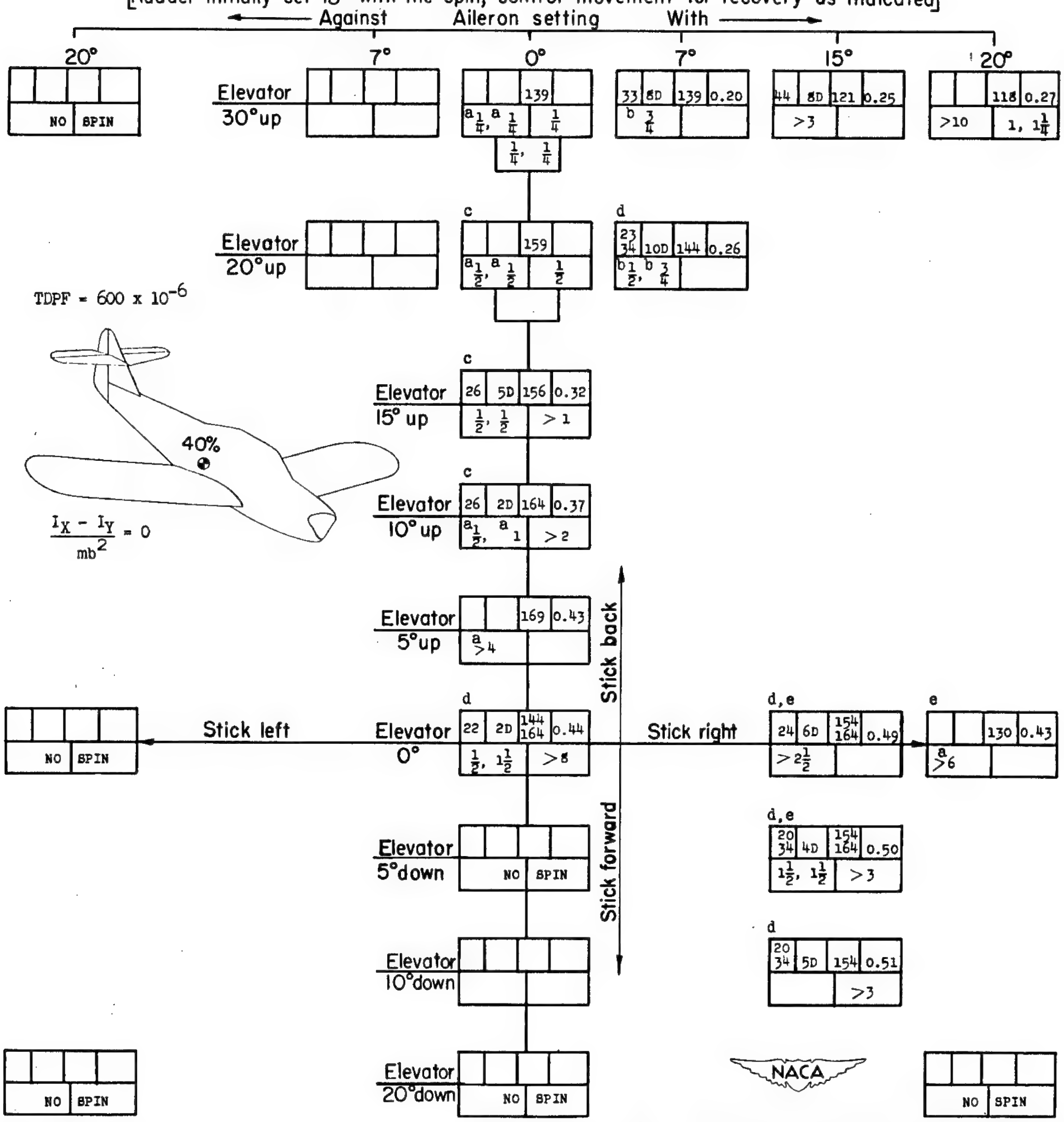
[Rudder initially set 30° with the spin; control movement for recovery as indicated]



[a] Oscillatory in pitch; range or average values given.
[b] Visual estimate.
[c] Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d] Whipping spin.
[e] Goes into an inverted spin after recovery from erect spin.
[f] Goes into an inverted glide.

CHART 20.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 20 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



[a]Visual estimate.
[b]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Wandering spin.
[d]Oscillatory in pitch; range or average values given.
[e]Whipping spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	
Turns for recovery: Rudder 15° with to 15° against; Elevator reversed to full down.			

CHART 21.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 21 LISTED IN TABLE III

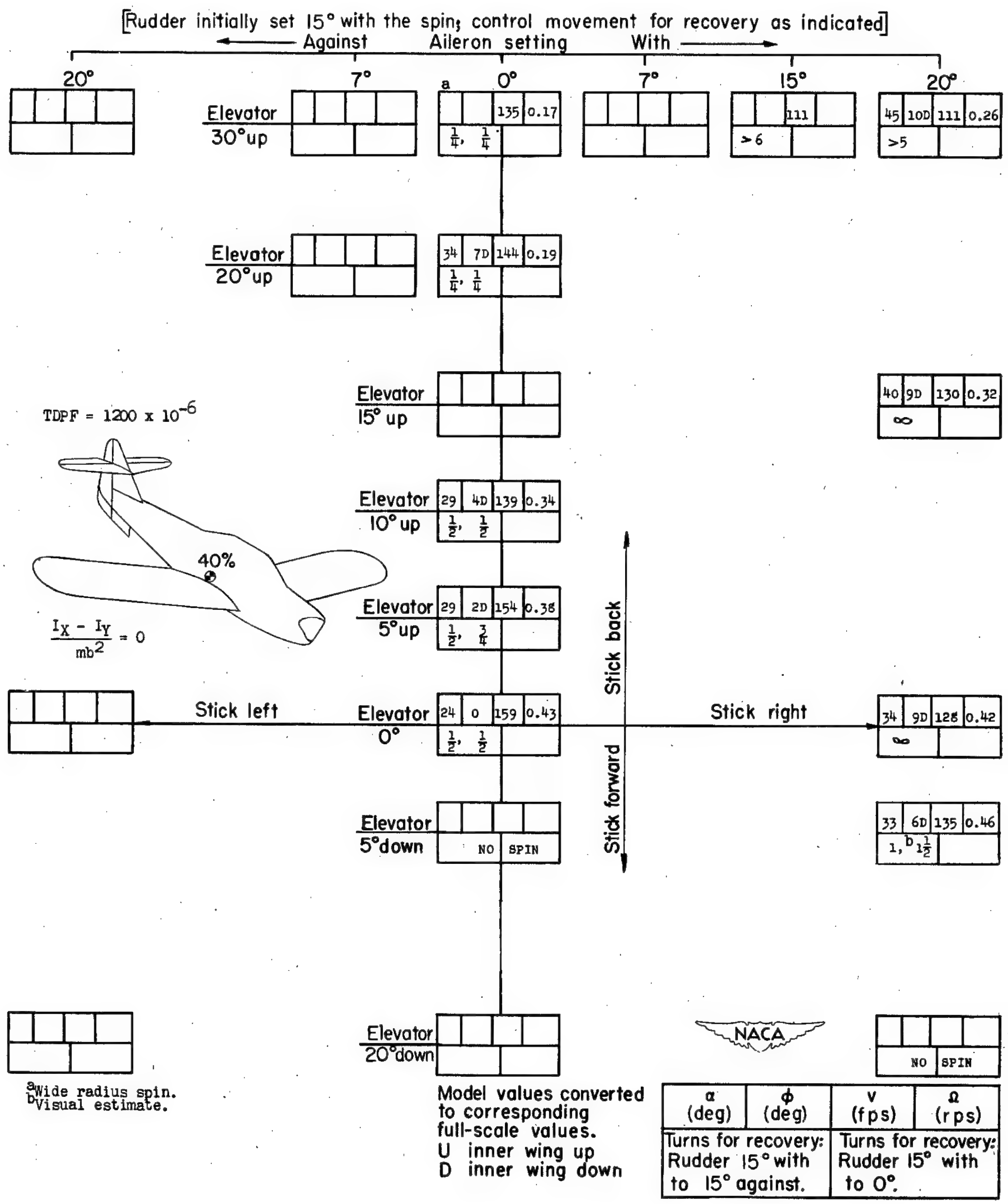
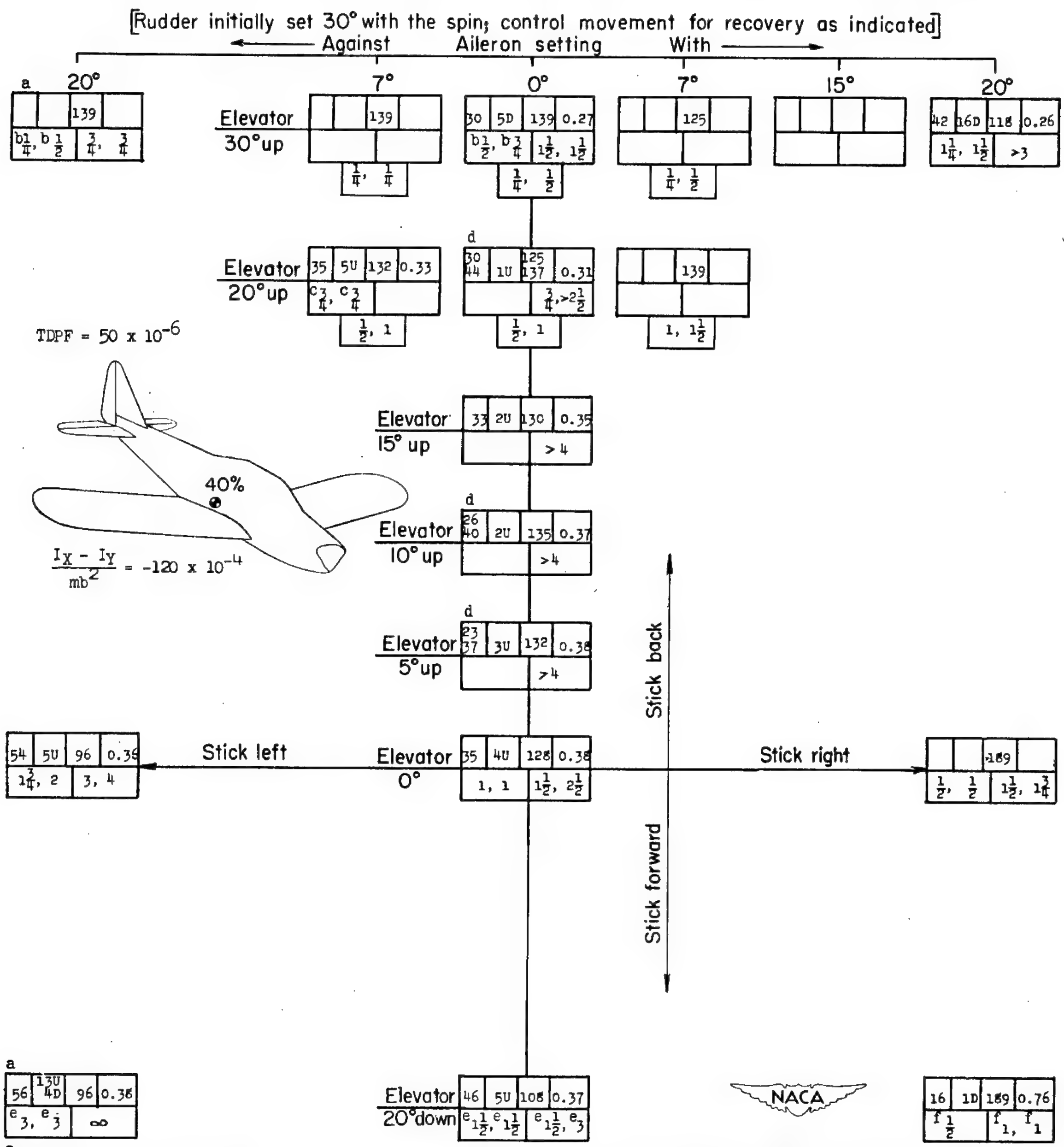


CHART 22.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 22 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



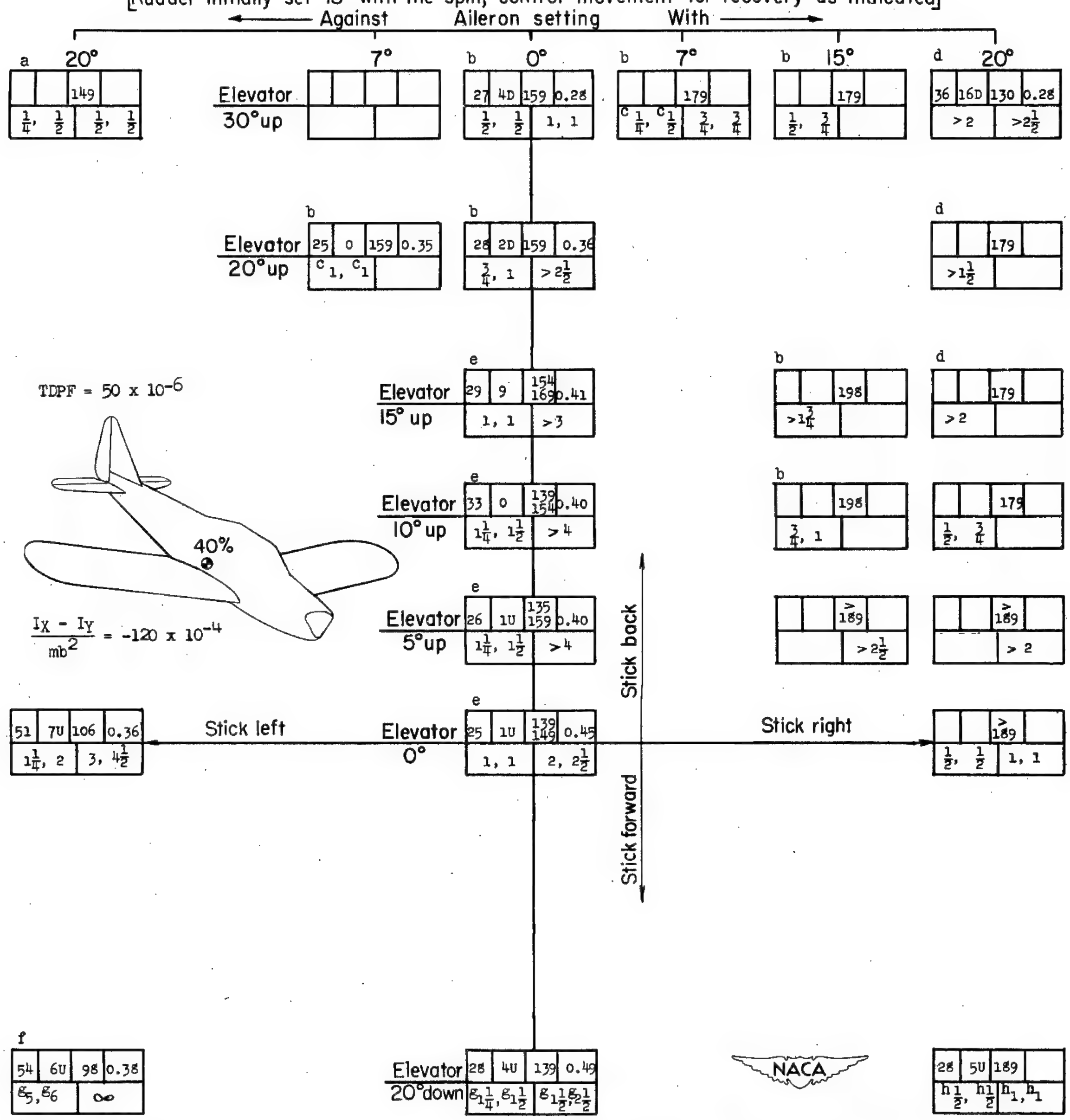
[a]Oscillatory in roll and yaw.
[b]Goes into a spin to the left after recovery from right spin.
[c]Rudder reversed to only 20° (2/3 of its full deflection) against the spin.
[d]Oscillatory in pitch; range or average values given.
[e]Goes into an inverted glide.
[f]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	
Turns for recovery: Rudder 30° with to 0°. Elevator neutralized.			

CHART 23.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 23 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]

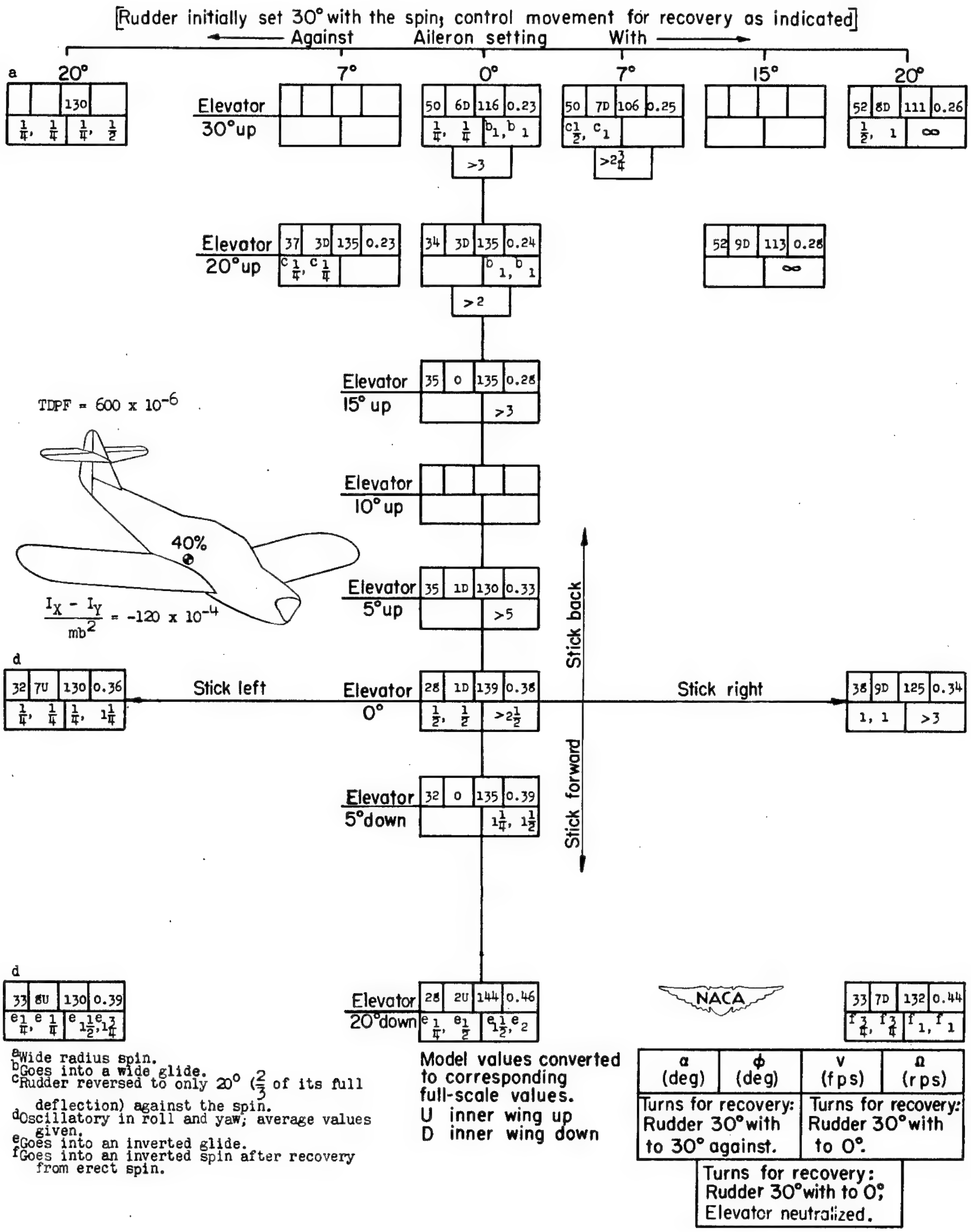


aWide radius spin.
bWandering spin.
cRudder reversed to only 10° (2/3 of its full deflection) against the spin.
dWandering spin with a whip.
eOscillatory in pitch; range or average values given.
fOscillatory in roll and yaw; average values given.
gGoes into an inverted glide.
hGoes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 24.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 24 LISTED IN TABLE III



[a]Wide radius spin.
[b]Goes into a wide glide.
[c]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Oscillatory in roll and yaw; average values given.
[e]Goes into an inverted glide.
[f]Goes into an inverted spin after recovery from erect spin.

CHART 25.– SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 25 LISTED IN TABLE III

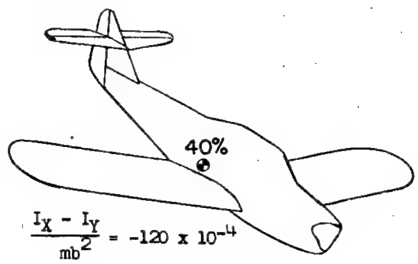
[Rudder initially set 15° with the spin; control movement for recovery as indicated]

← Against   Aileron setting   With →

Elevator 30° up

Aileron				
20° (against)				
	NO SPIN			
0° [a]			116	
	$\frac{1}{4}$, $\frac{1}{4}$			
7° (with)	42	9D	121	0.21
	b $\frac{1}{2}$, b $\frac{3}{4}$			
20° (with)	47	12D	106	0.23
	∞			

TDPF = 600 x 10^{-6}



$\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}$

Stick back

Elevator 0°

Stick left	27	5U	154	0.38
	$\frac{1}{2}$, $\frac{1}{2}$			
Neutral [c]	22	6D	164–184	0.39
	$\frac{1}{2}$, $\frac{3}{4}$			
Stick right [d]			189	
	$\frac{1}{2}$, $\frac{3}{4}$			

Stick forward

Elevator 20° down

Stick left [e]	29	9U	135	0.42
	f $\frac{3}{4}$, f $\frac{3}{4}$			
Neutral	19	3D	184	0.56
	f $\frac{1}{4}$, f $\frac{1}{2}$			
Stick right			234	
	g $\frac{1}{2}$, g $\frac{1}{2}$			

[a]Wide radius spin.
[b]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Oscillatory in pitch and wanders; range or average values given.
[d]Steep spin.
[e]Oscillatory in roll and yaw; average values given.
[f]Goes into an inverted glide.
[g]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

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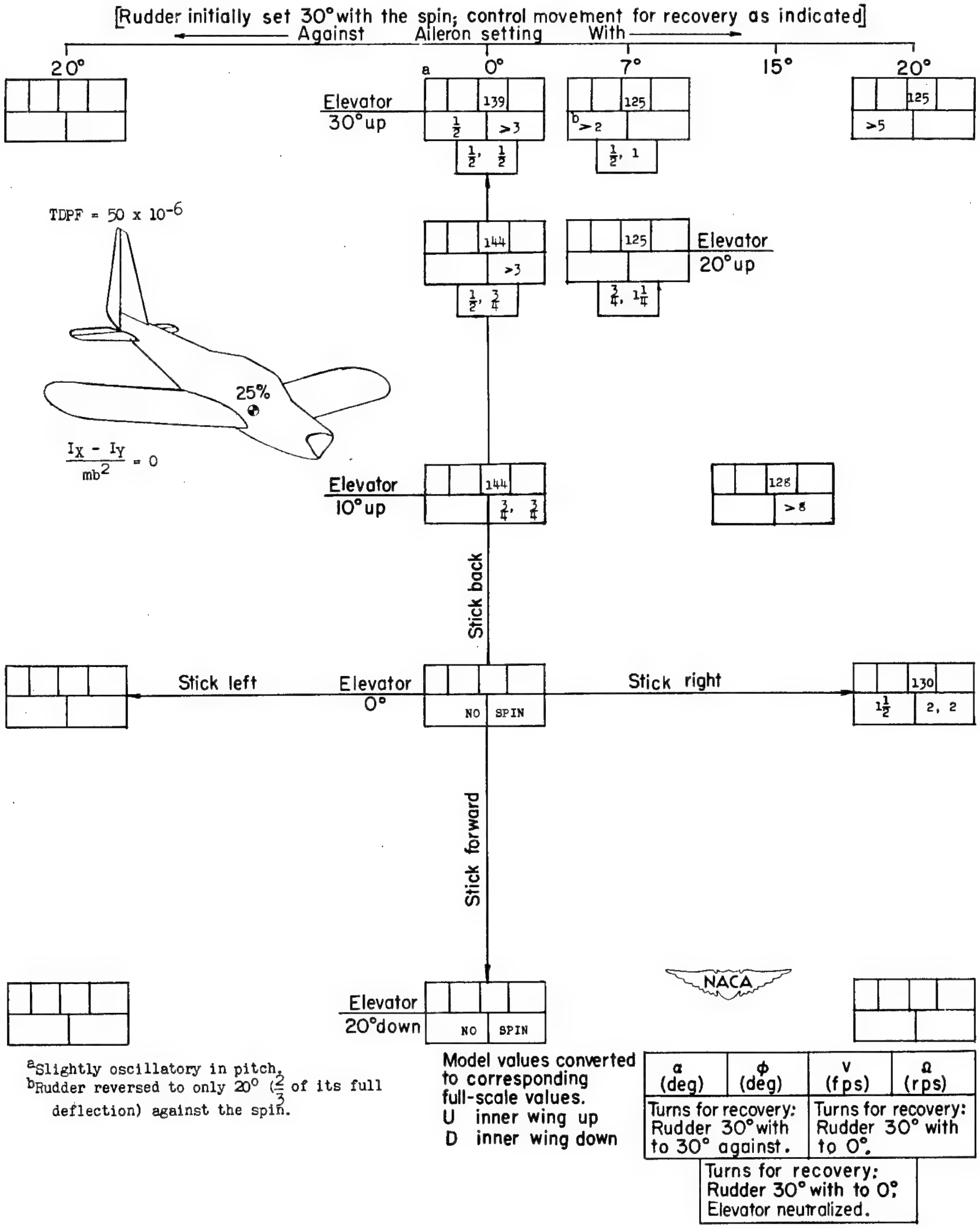
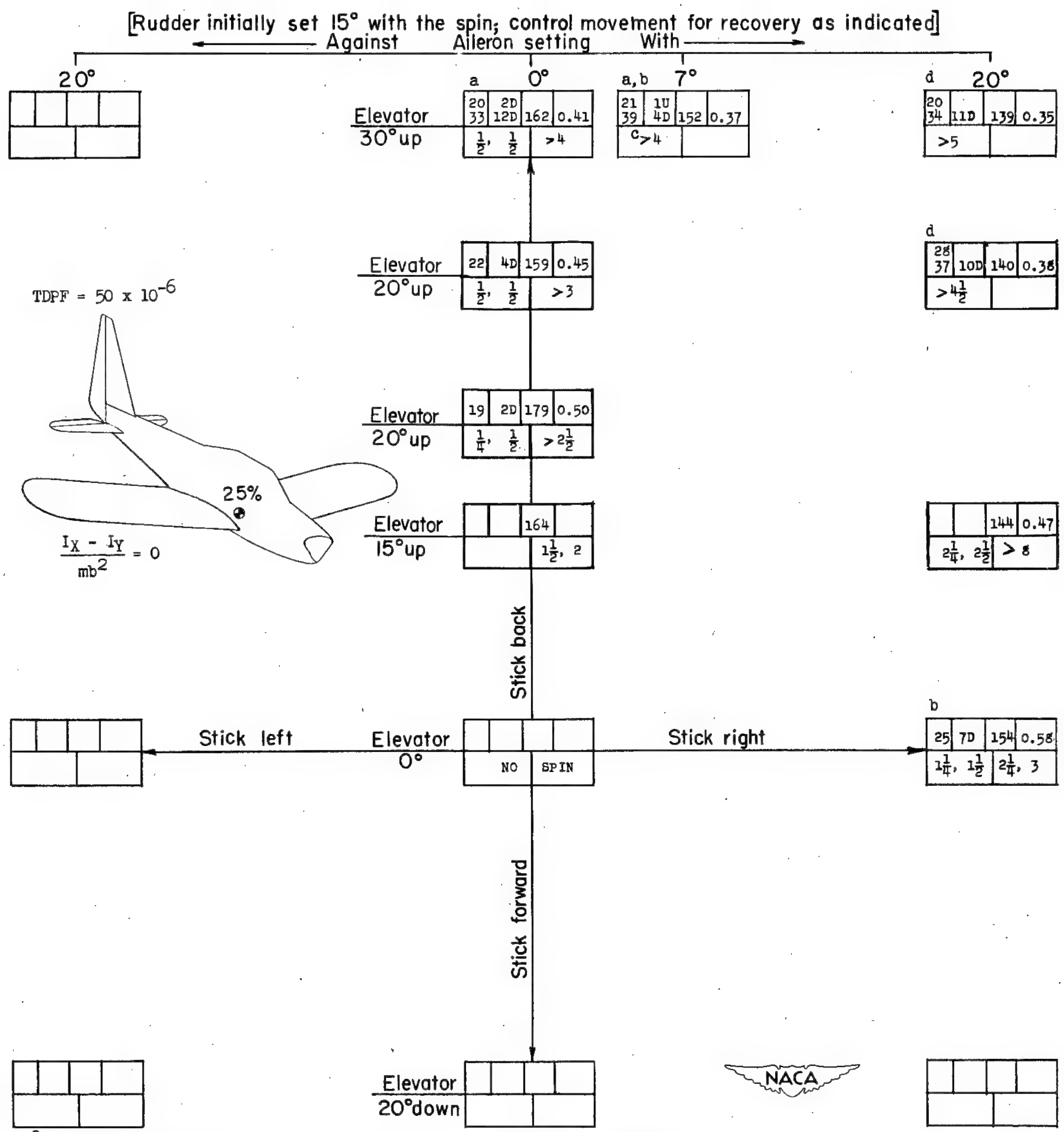
CHART 26.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 26 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



[a]Slightly oscillatory in pitch.
[b]Rudder reversed to only 20° (2/3 of its full deflection) against the spin.

CHART 27.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 27 LISTED IN TABLE III



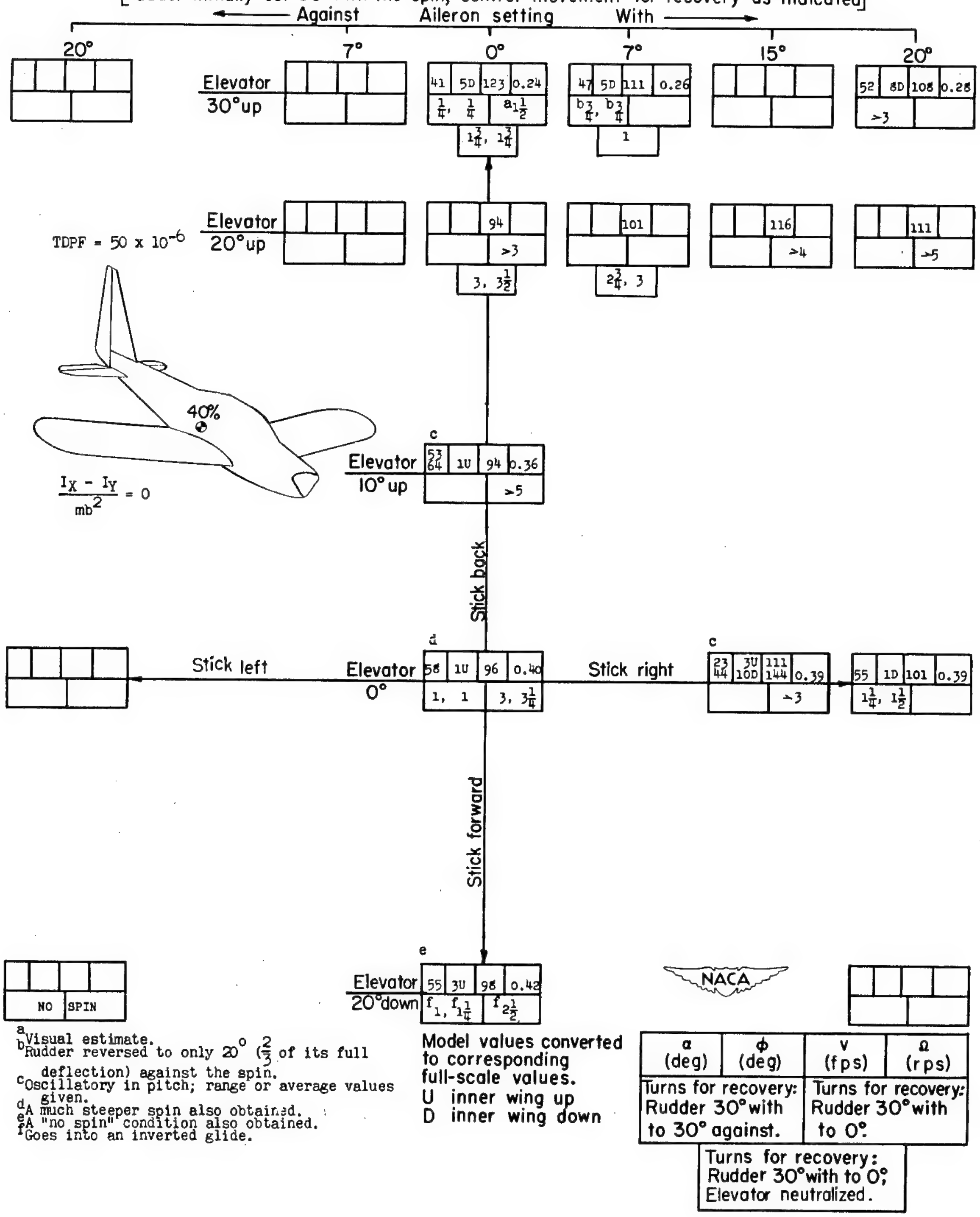
[a]Oscillatory in pitch, roll, and yaw; range or average values given.
[b]Whipping spin.
[c]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Oscillatory in pitch; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 28.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 28 LISTED IN TABLE III

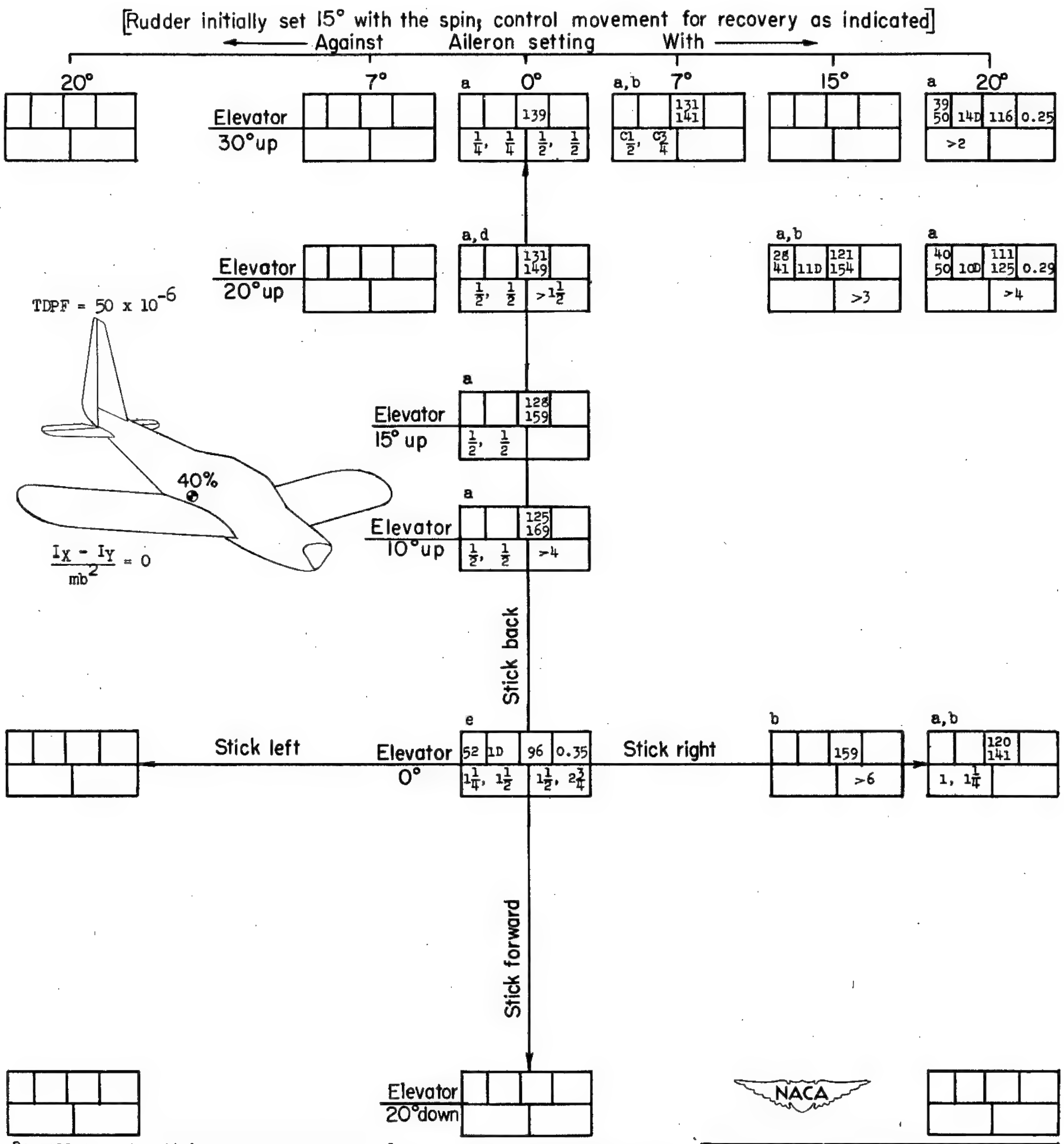
[Rudder initially set 30° with the spin; control movement for recovery as indicated]



Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

[a] Visual estimate.
[b] Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[c] Oscillatory in pitch; range or average values given.
[d] A much steeper spin also obtained.
[e] A "no spin" condition also obtained.
[f] Goes into an inverted glide.

CHART 29.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 29 LISTED IN TABLE III



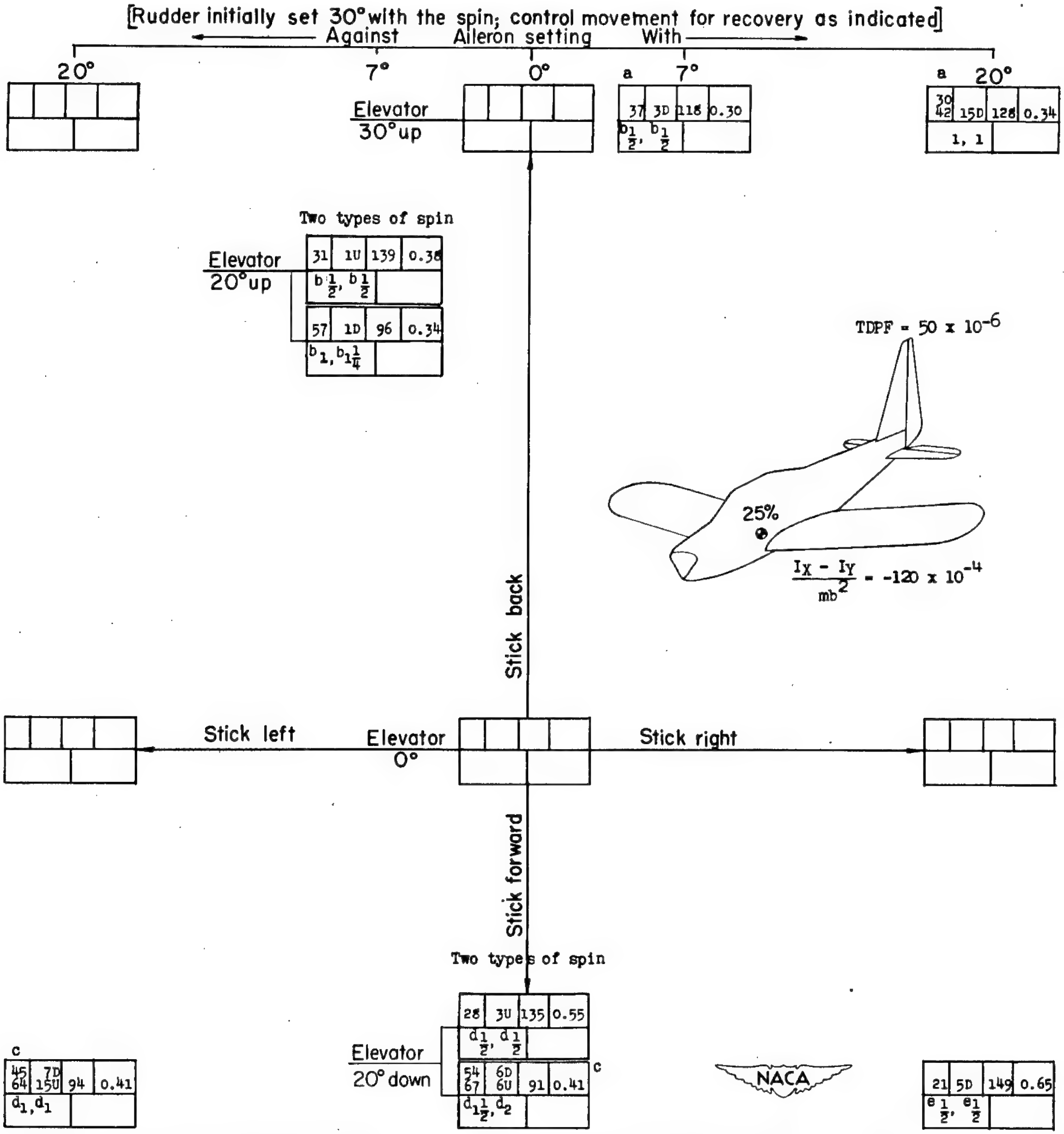
[a]Oscillatory in pitch; range or average values given.
[b]Whipping spin.
[c]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Wandering spin.
[e]A "no spin" condition also obtained.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 30.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 30 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]

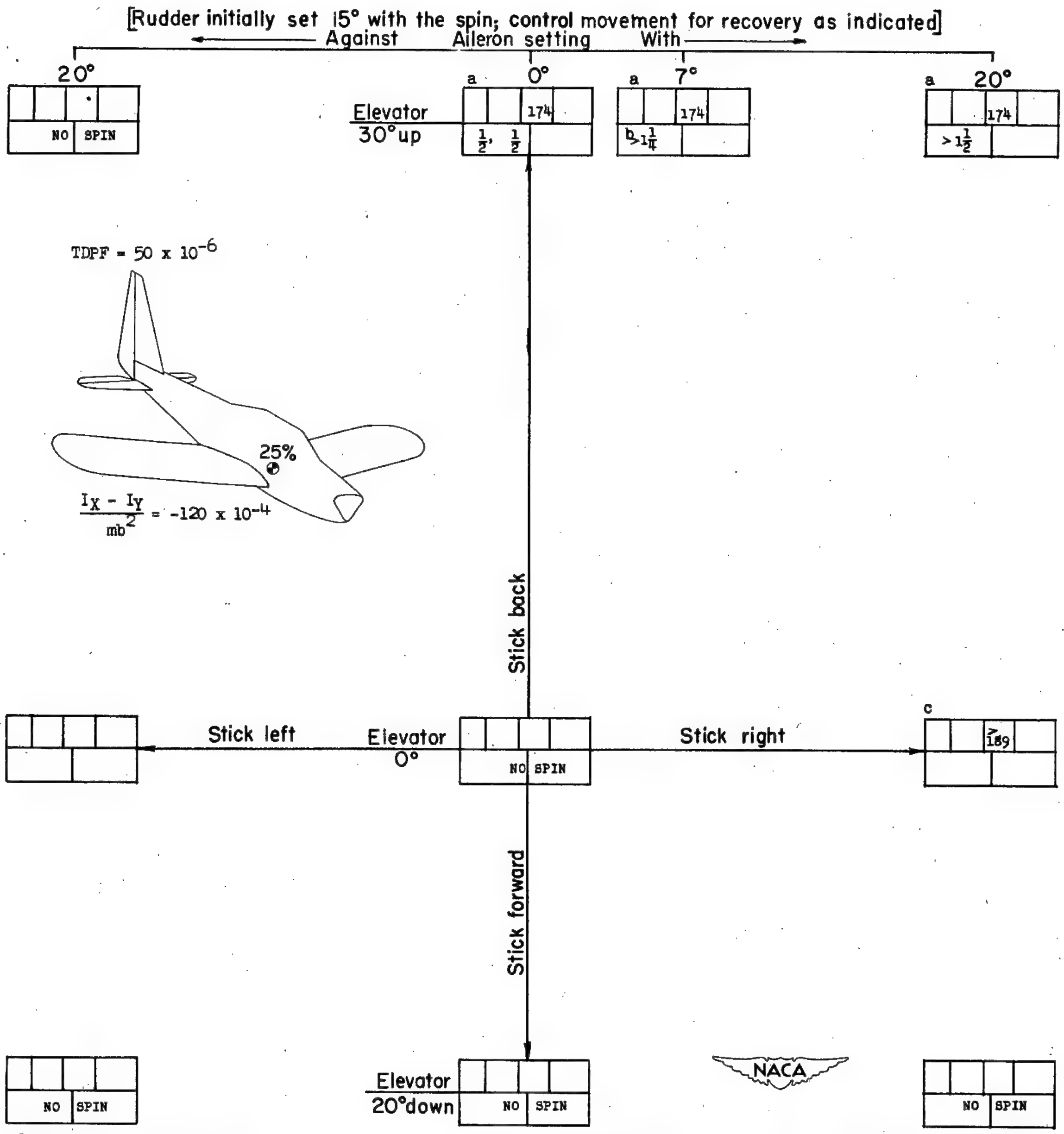


[a]Slightly oscillatory in pitch; range or average values given.
[b]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Oscillatory in pitch, roll, and yaw; range or average values given.
[d]Goes into an inverted glide.
[e]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 31.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 31 LISTED IN TABLE III

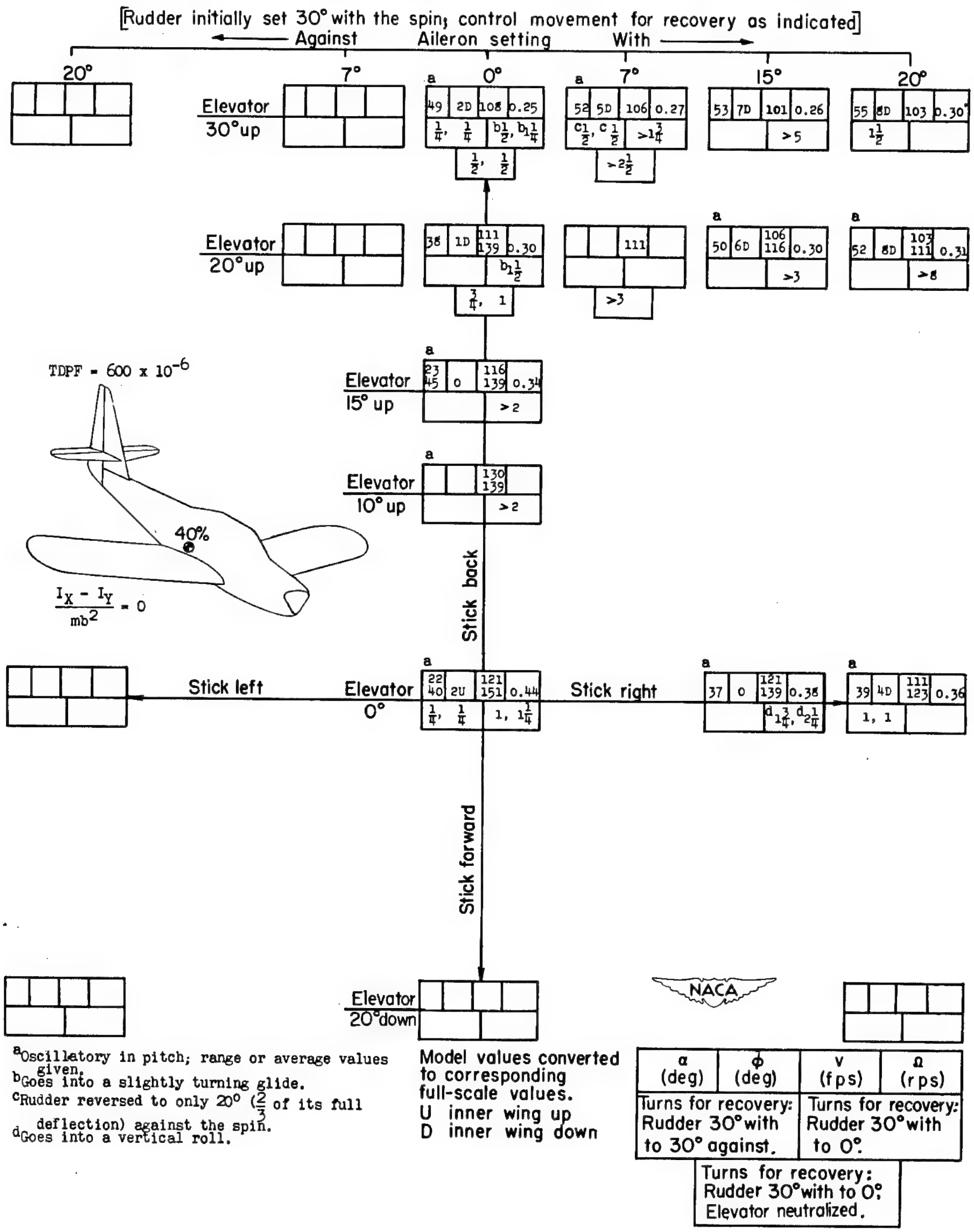


[a]Whipping spin and wanders.
[b]Visual estimate. Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Extremely steep spin. Recovery by rudder reversal would probably have been very rapid.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 32.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 32 LISTED IN TABLE III

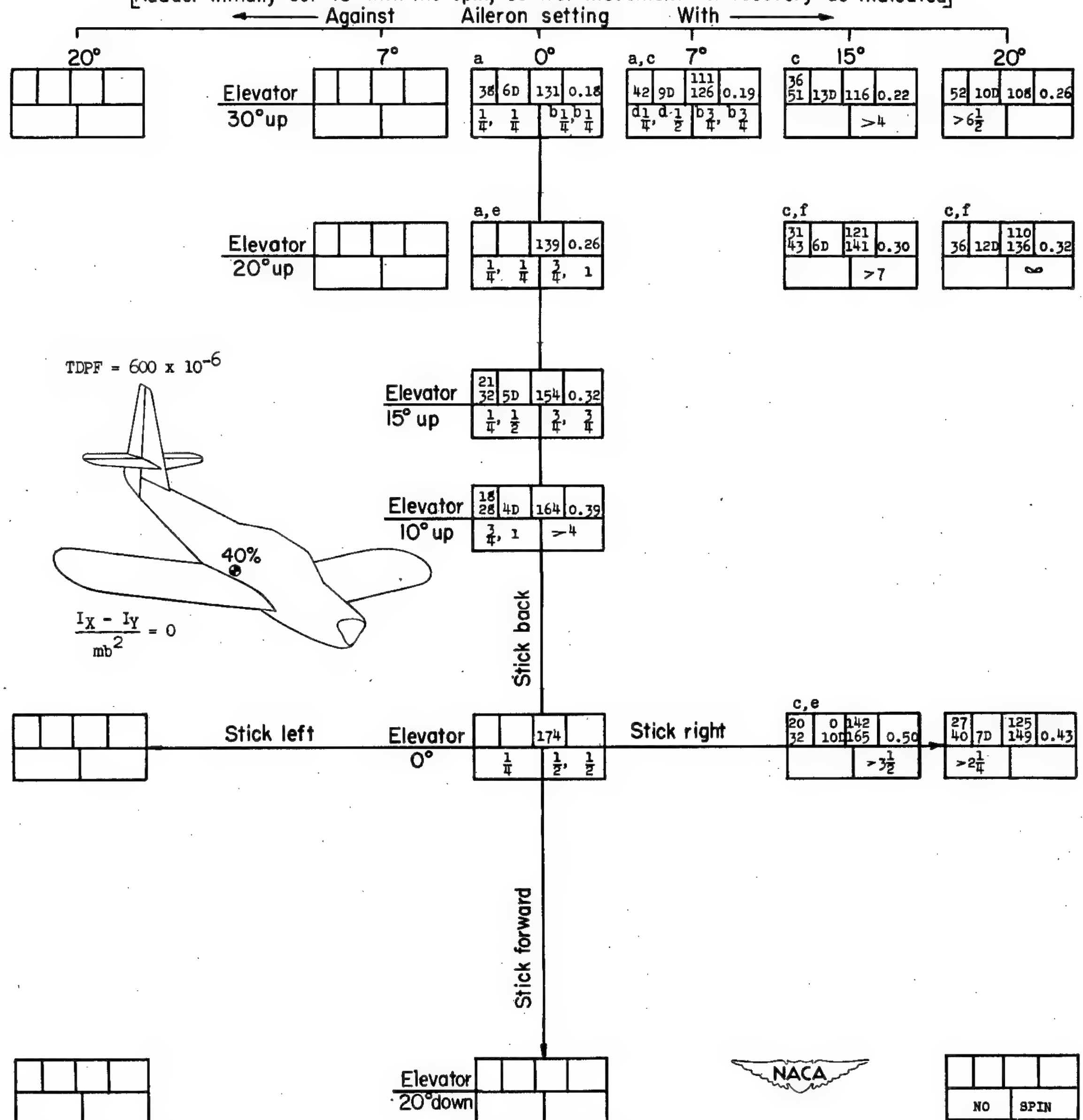


[a] Oscillatory in pitch; range or average values given.
[b] Goes into a slightly turning glide.
[c] Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d] Goes into a vertical roll.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

CHART 33.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 33 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



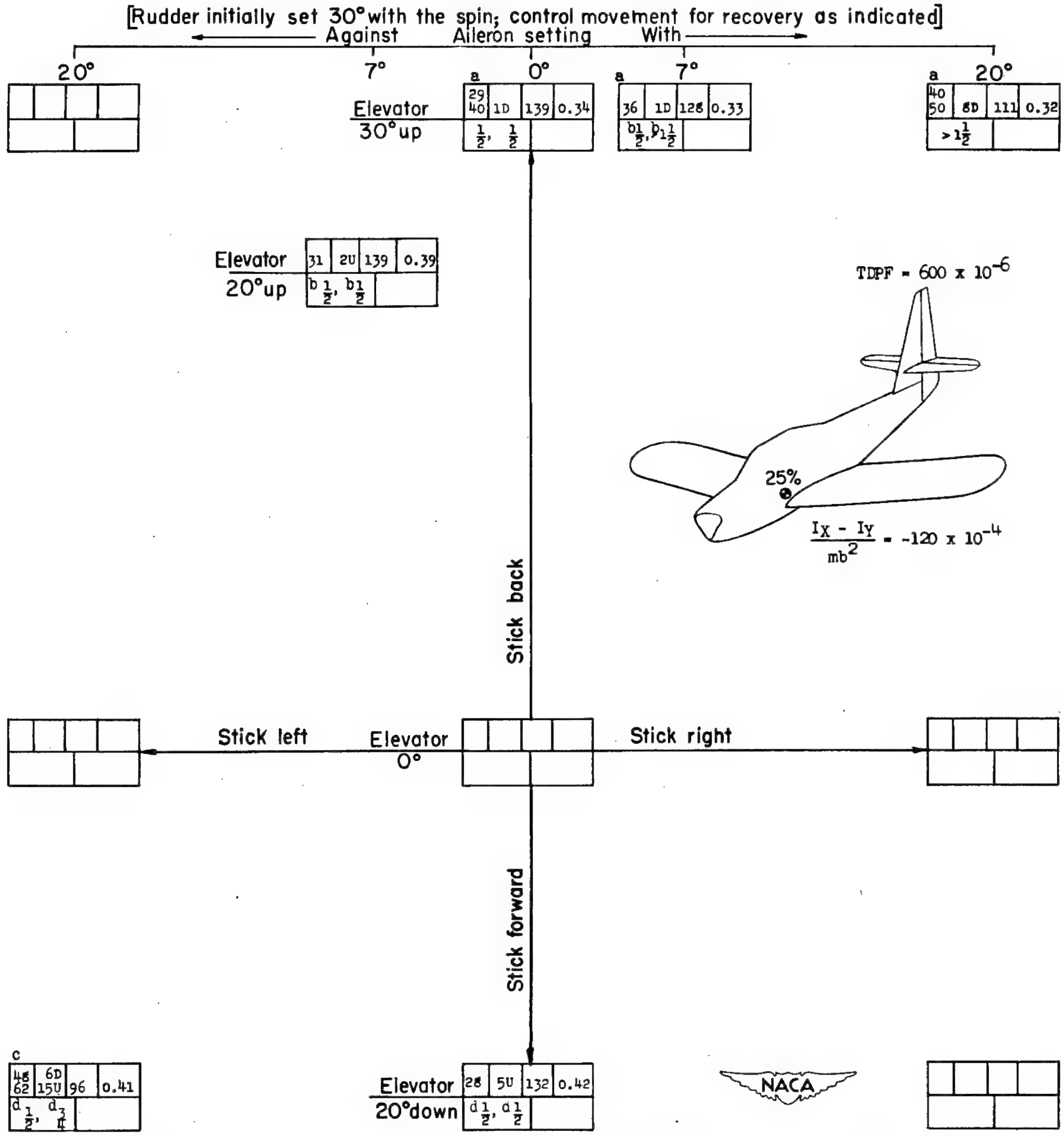
[a]Wide radius spin.
[b]Goes into a slightly turning glide.
[c]Oscillatory in pitch; range or average values given.
[d]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Wandering spin.
[f]Whipping spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 34.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 34 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



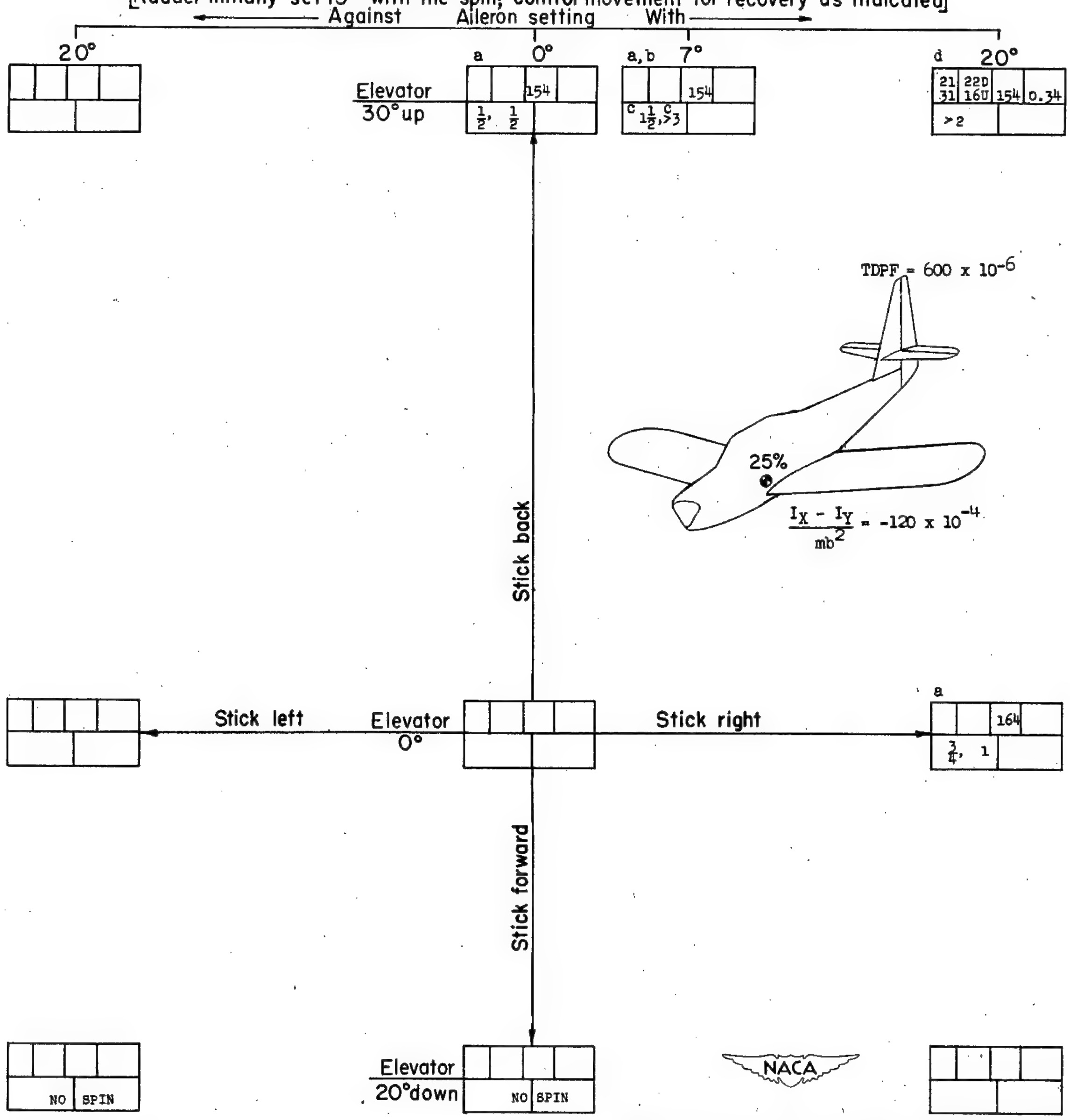
[a]Oscillates in pitch; range or average values given.
[b]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Oscillatory in pitch, roll, and yaw; range or average values given.
[d]Goes into an inverted glide.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 35.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 35 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



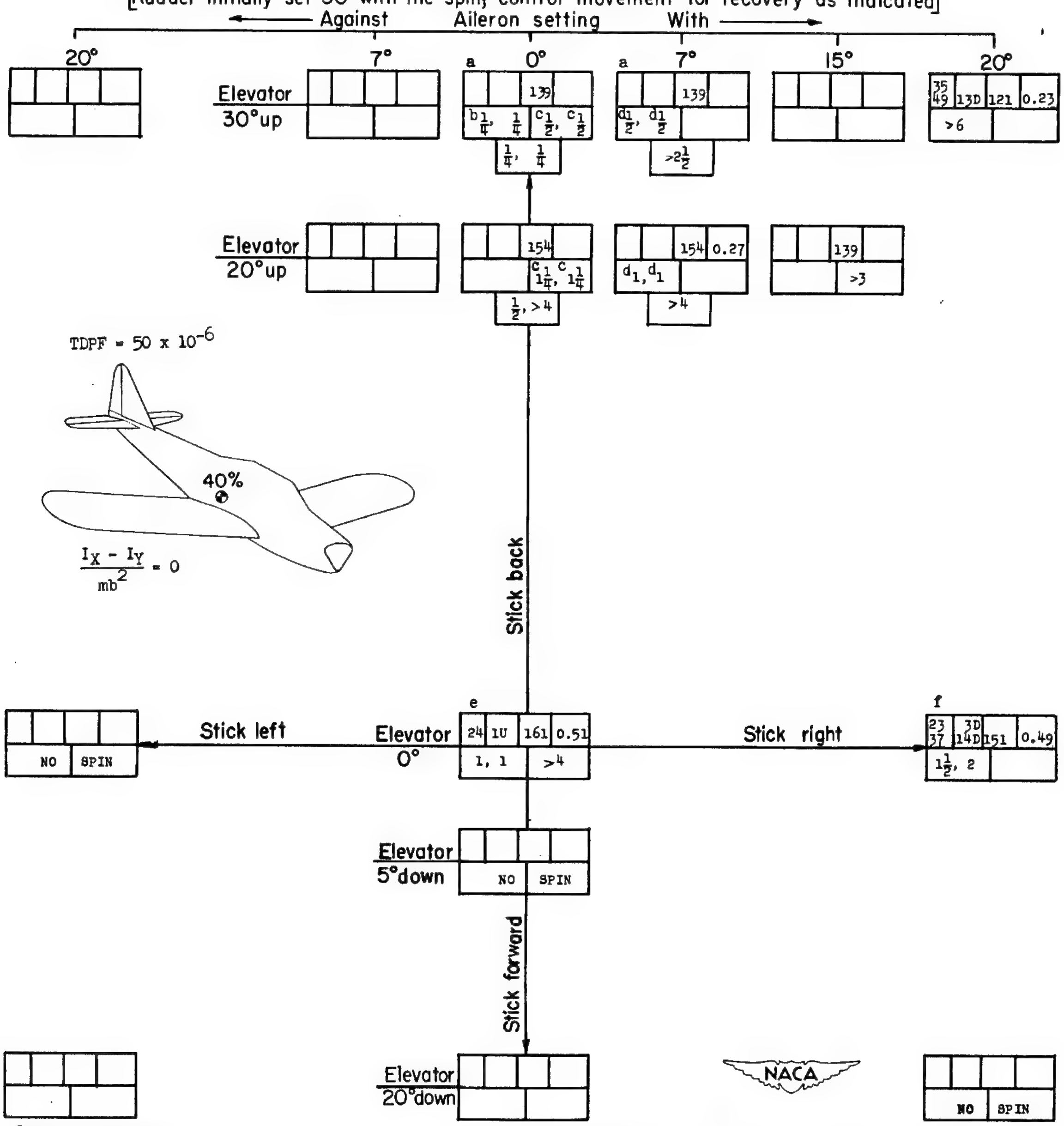
[a]Wandering spin.
[b]Whipping spin.
[c]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Oscillatory in pitch, roll, and yaw; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 36.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 36 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]

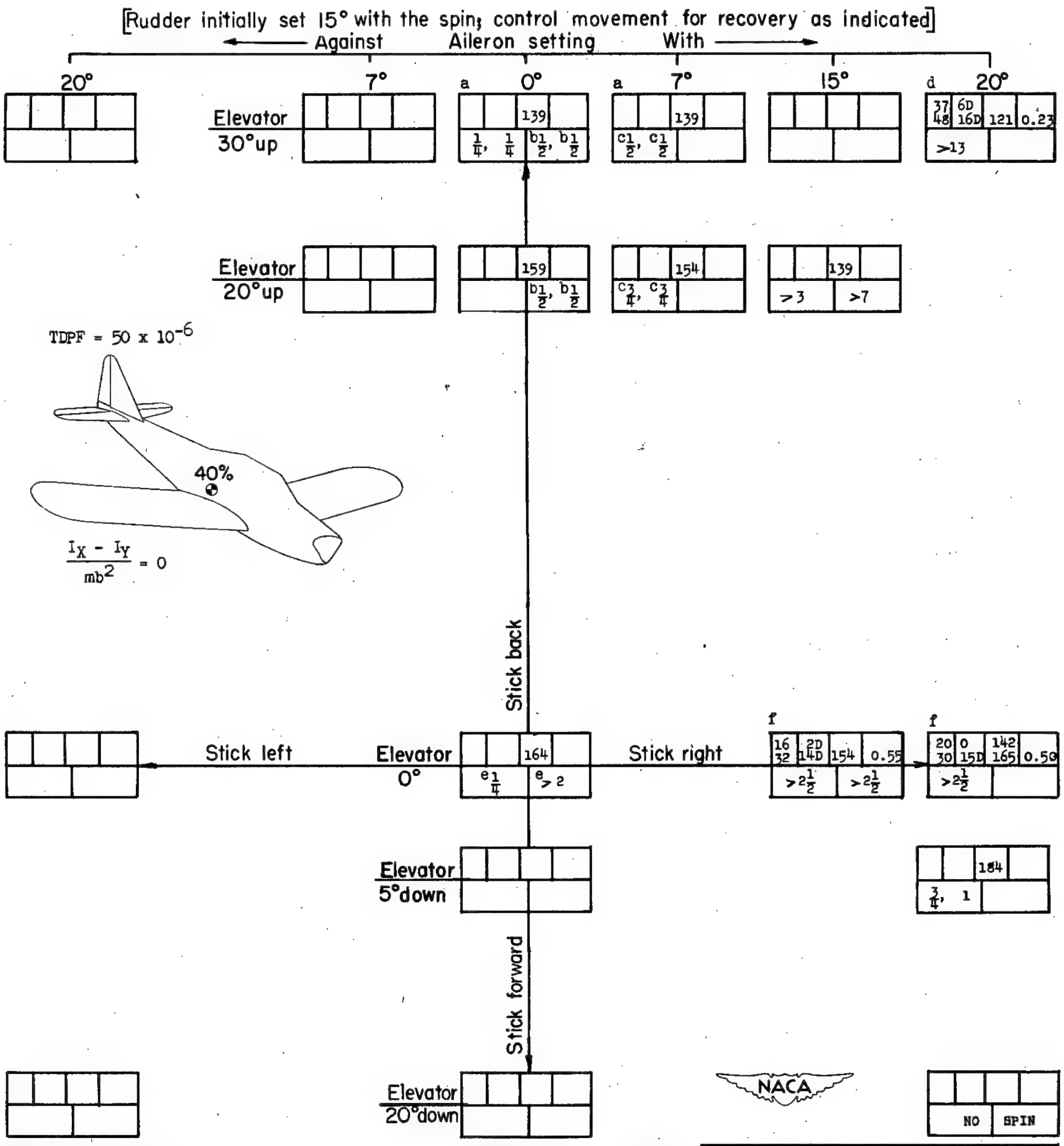


[a]Wide radius spin.
[b]Visual estimate.
[c]Goes into a slightly turning glide.
[d]Rudder reversed to only 20° (2/3 of its full deflection) against the spin.
[e]Oscillatory in pitch; average values given.
[f]Oscillatory spin with a whip; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	
Turns for recovery: Rudder 30° with to 0°. Elevator neutralized.			

CHART 37.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 37 LISTED IN TABLE III



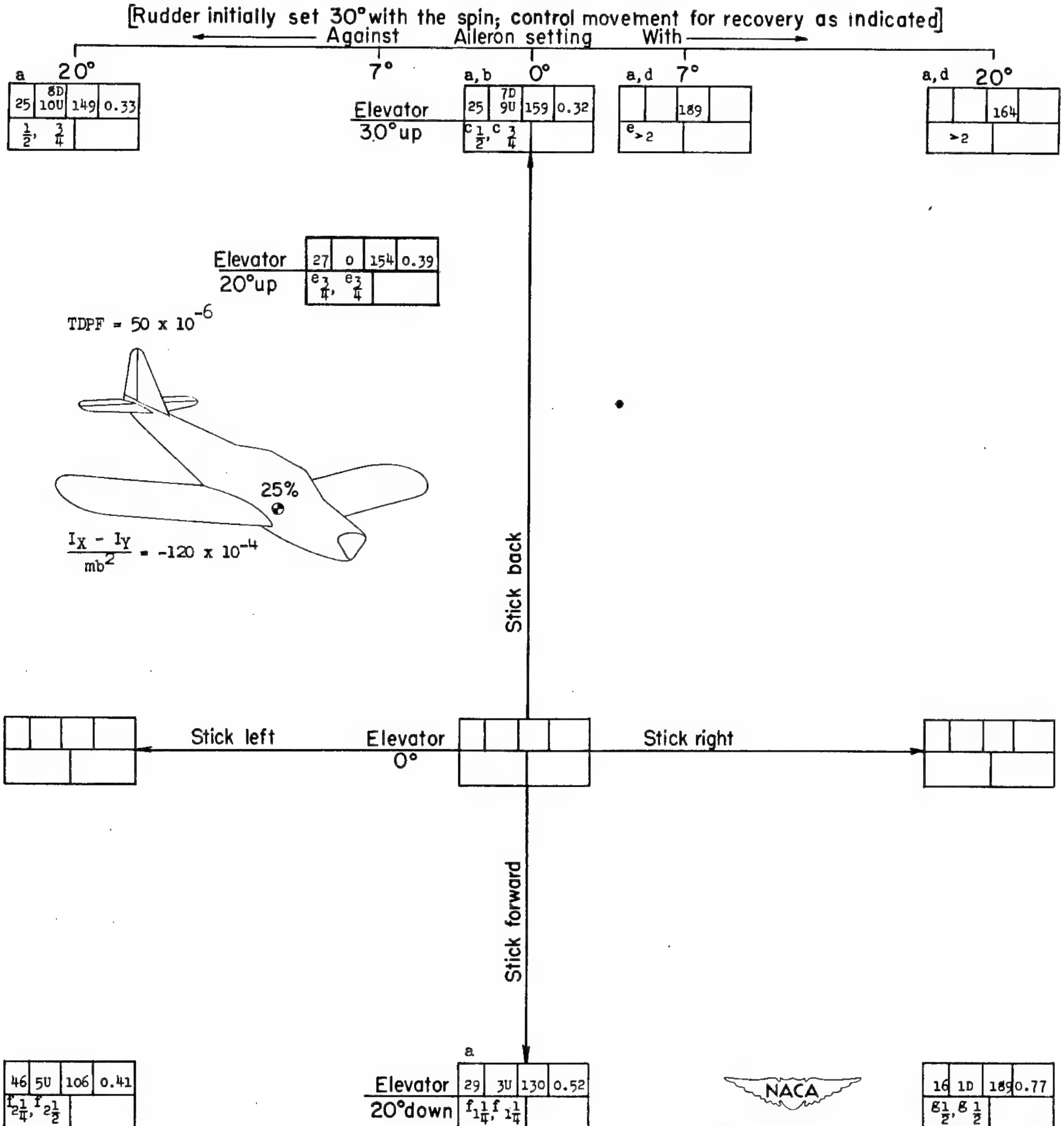
aWide radius spin.
bGoes into a slightly turning glide.
cRudder reversed to only 10° (2/3 of its full deflection) against the spin.
dSlightly oscillatory in pitch, roll, and yaw; range or average values given.
eRecovery attempted before model reached final steep attitude.
fOscillatory in pitch, roll, and yaw and has a whip; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 38.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 38 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



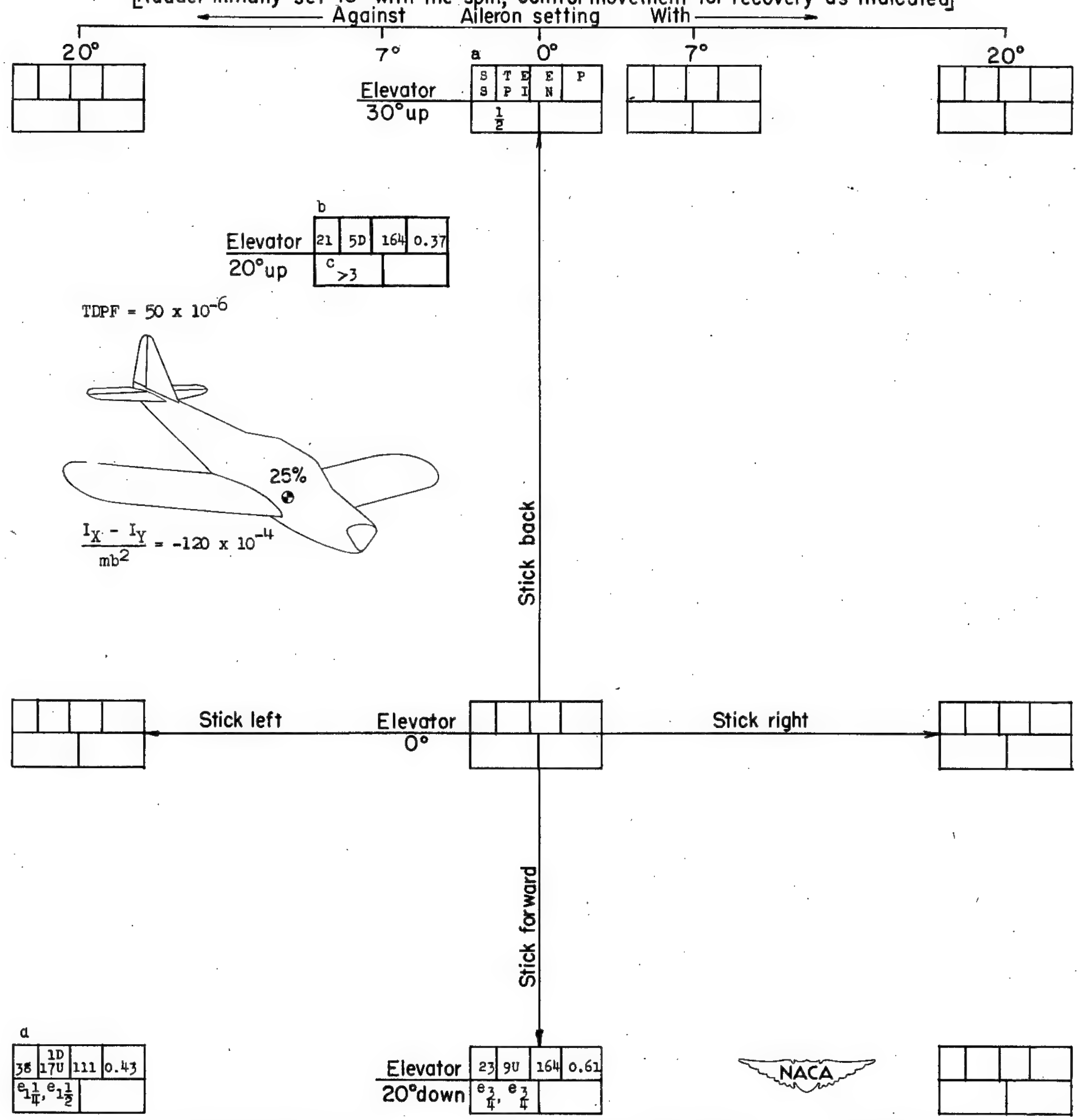
[a] Wandering spin.
[b] Oscillatory in roll and yaw; range of values given.
[c] Goes into a slightly turning glide.
[d] Whipping spin.
[e] Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin. Visual estimate.
[f] Goes into an inverted glide.
[g] Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 39.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 39 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



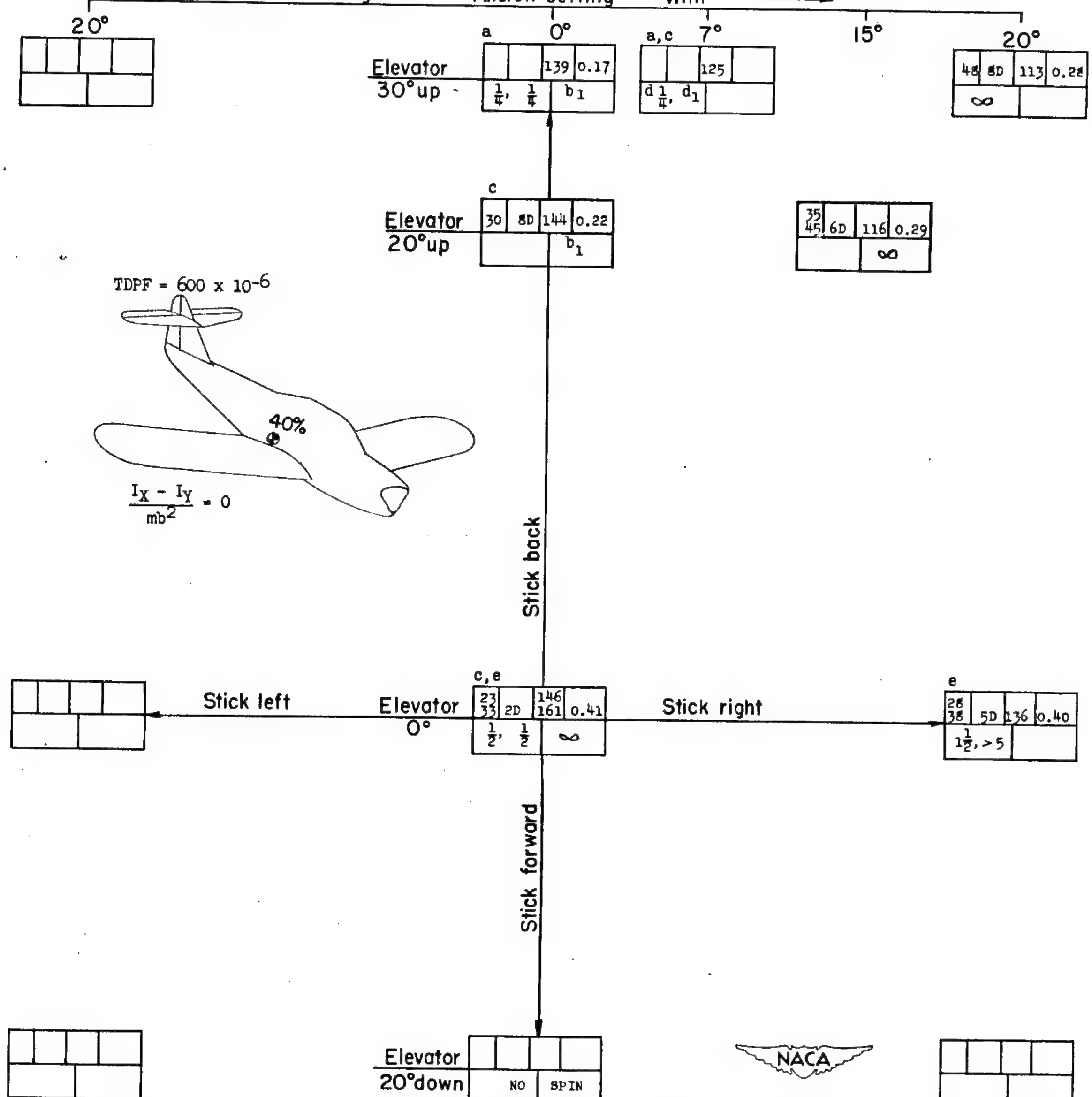
[a]Steep spin with a wide radius and wanders.
[b]Wandering spin.
[c]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Oscillatory in roll and yaw; range of values given.
[e]Goes into an inverted glide.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 40.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 40 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



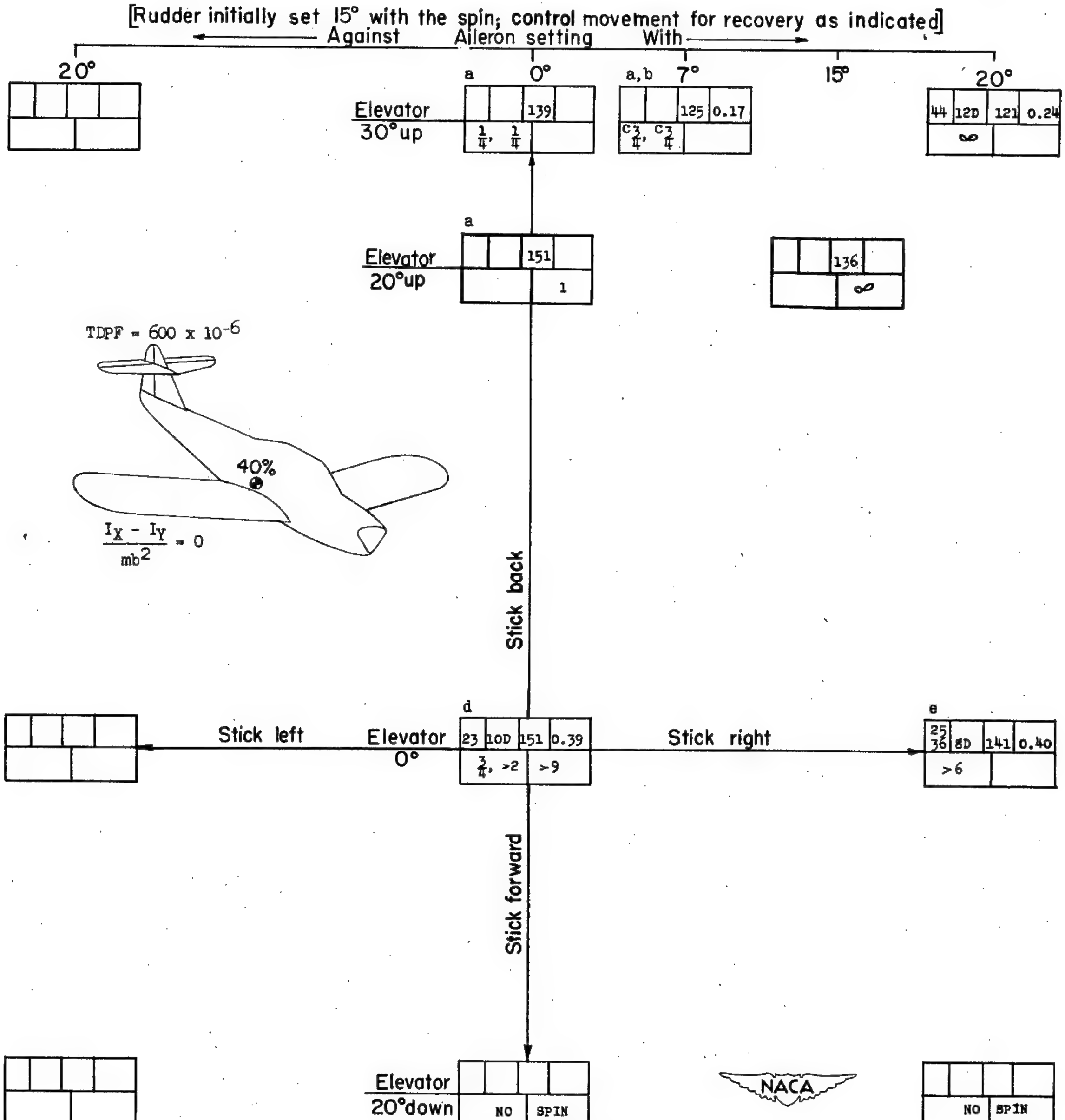
[a]Wide radius spin.
[b]Goes into a slightly turning glide.
[c]Whipping spin.
[d]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Oscillatory in pitch; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 41.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 41 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]

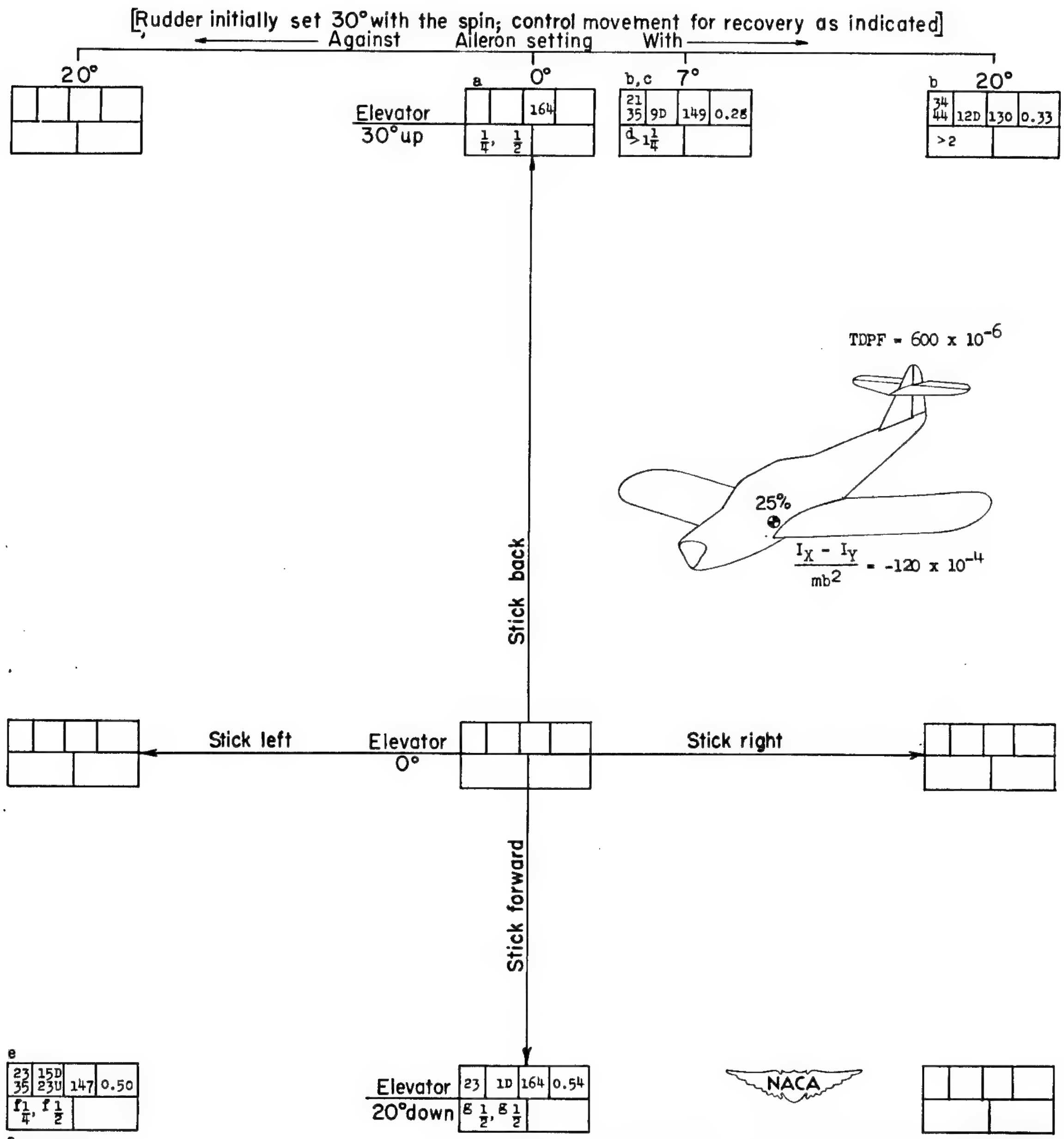


aWide radius spin.
bWhipping spin.
cRudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin. Goes into a slightly turning glide.
dA "no spin" condition also obtained.
eSlightly oscillatory in pitch.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 42.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 42 LISTED IN TABLE III



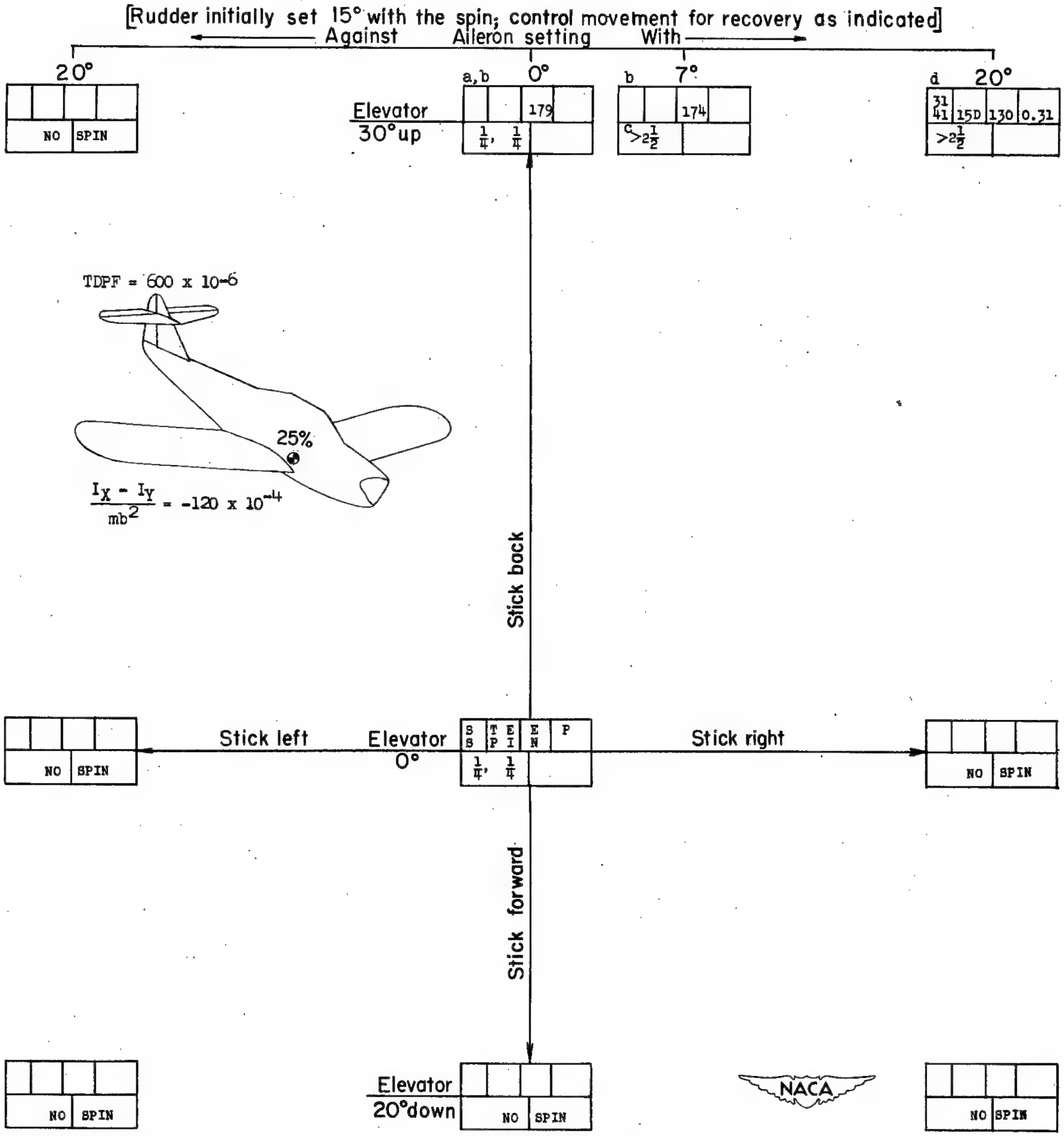
[a]Wide radius spin.
[b]Oscillatory in pitch; range or average values given.
[c]Wandering spin.
[d]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Oscillatory in pitch, roll, and yaw; range or average values given.
[f]Goes inverted and then begins to spin in a left erect spin after recovery from right spin.
[g]Goes into an inverted dive.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 43.—SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 43 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]

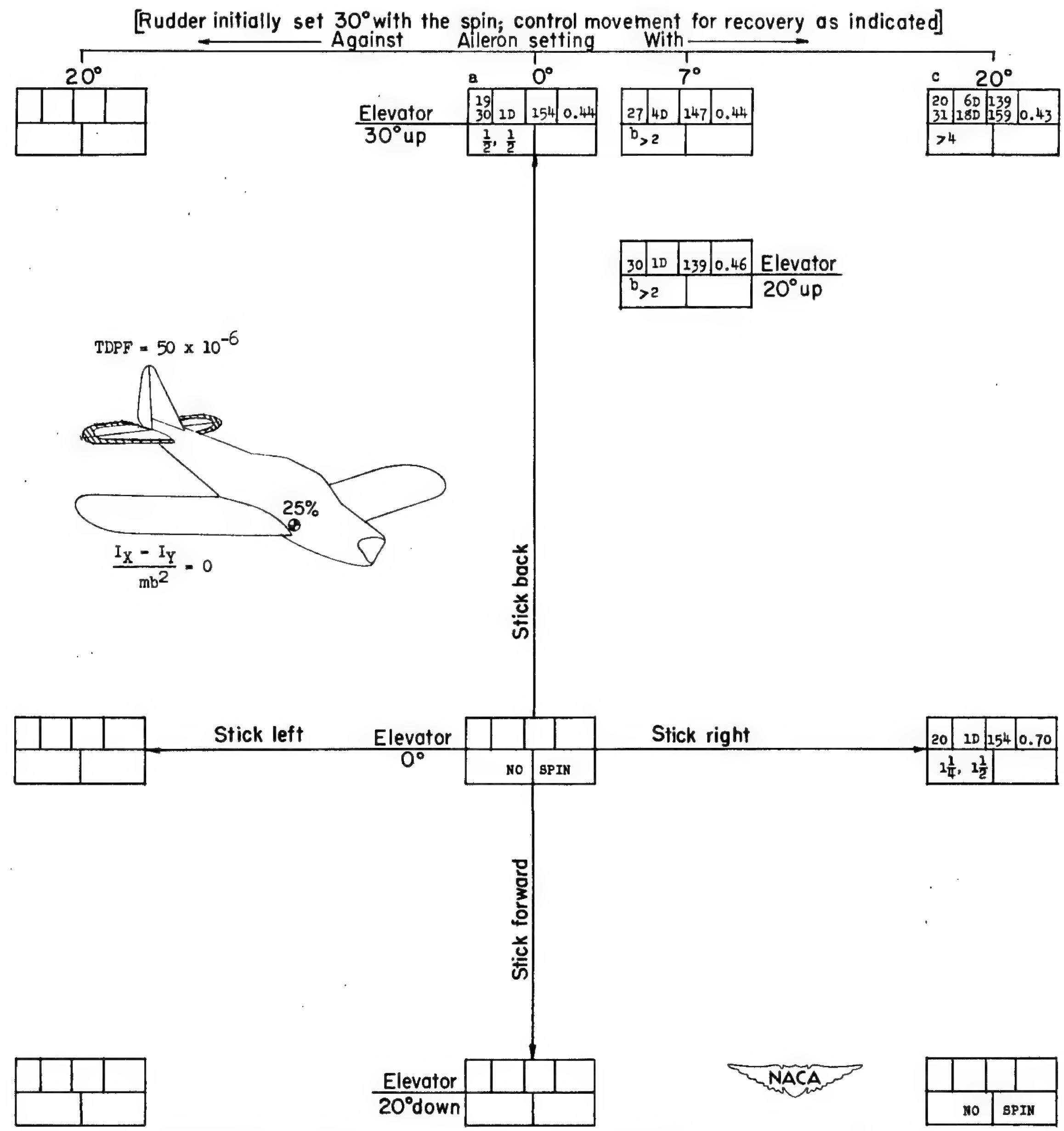


[a]Wide radius spin.
[b]Wandering spin.
[c]Visual estimate. Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Slightly oscillatory in pitch; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 44.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 44 LISTED IN TABLE III

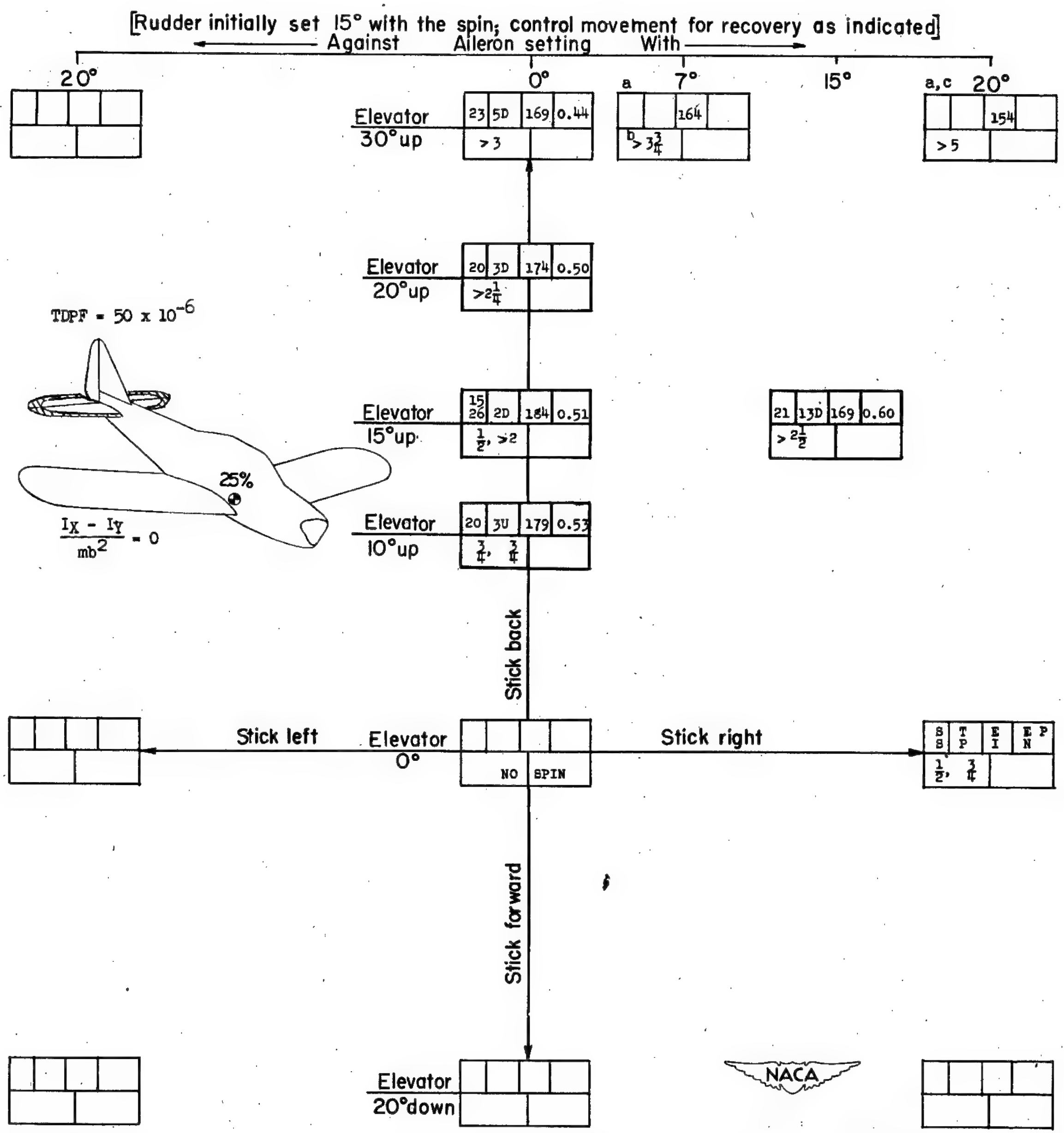


[a]Oscillatory in pitch; range or average values given.
[b]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Whipping spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 45.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 45 LISTED IN TABLE III



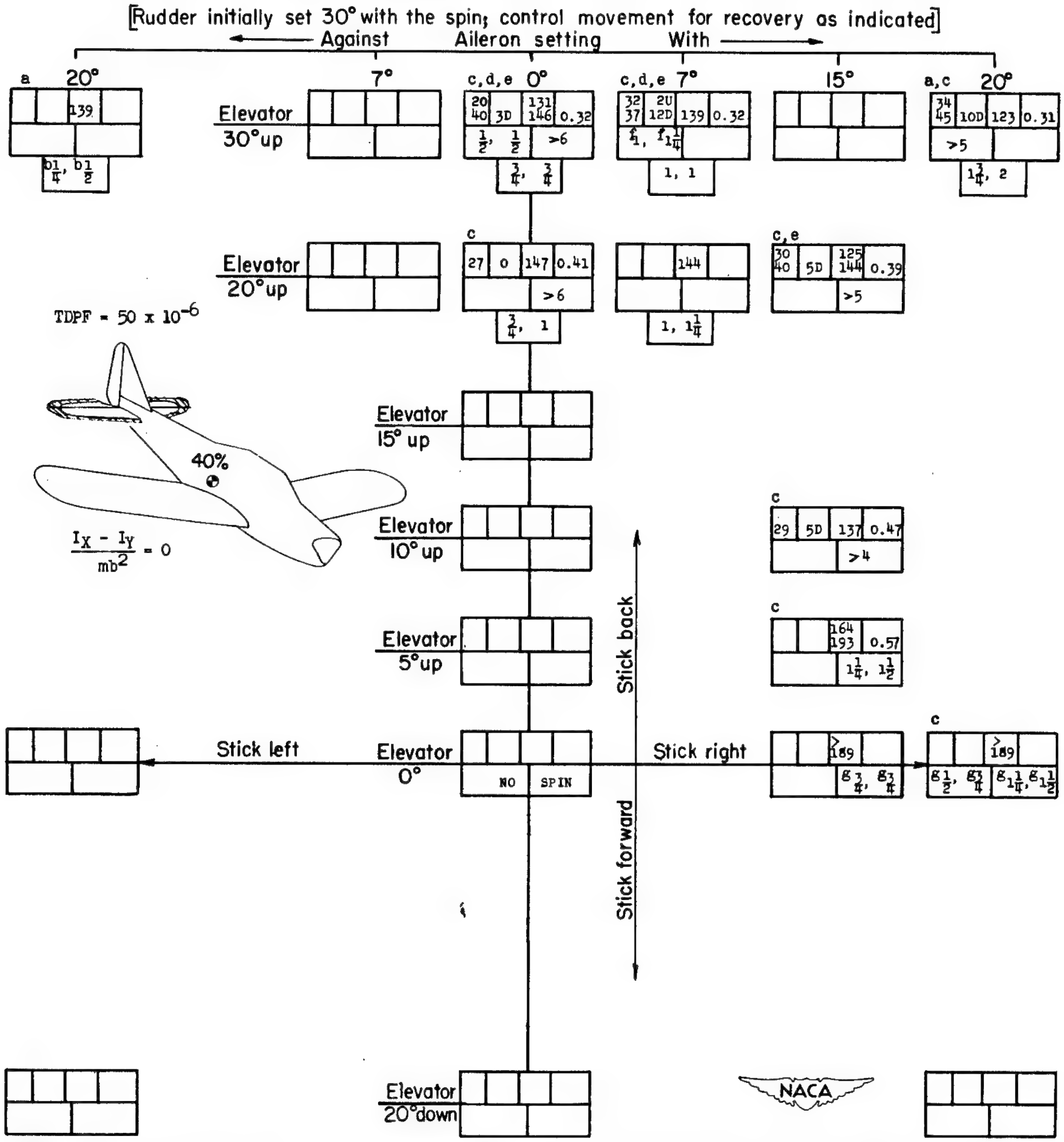
[a]Wandering spin.
[b]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Whipping spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 46.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 46 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



[a]Oscillatory in roll and yaw.
[b]Goes into a spin to the left after recovery from right spin.
[c]Oscillatory in pitch; range or average values given.
[d]Wandering spin.
[e]Whipping spin.
[f]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[g]Recovery attempted before model reached final steep attitude.

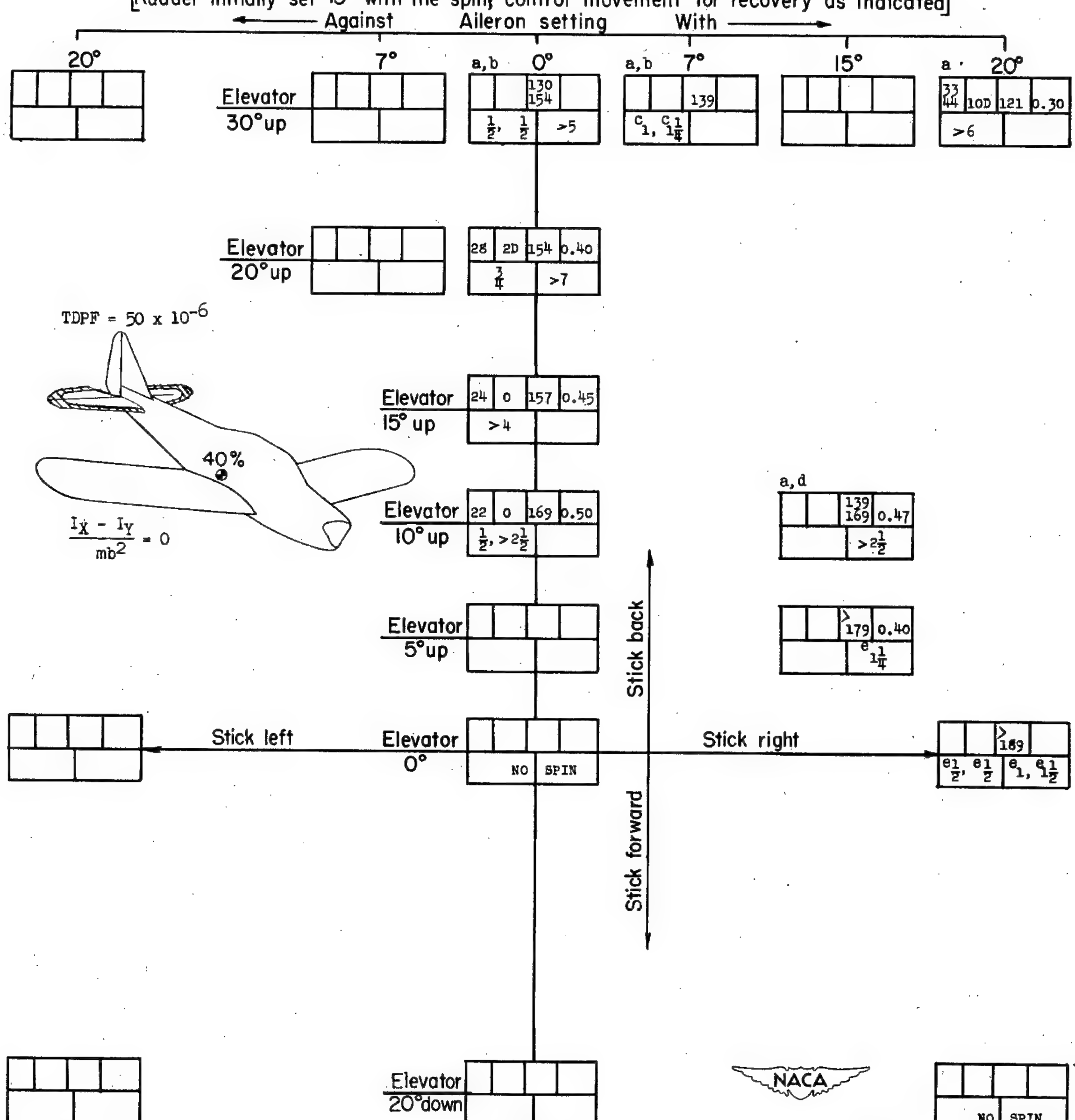
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

Turns for recovery: Rudder 30° with to 0°; Elevator neutralized.

CHART 47.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 47 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



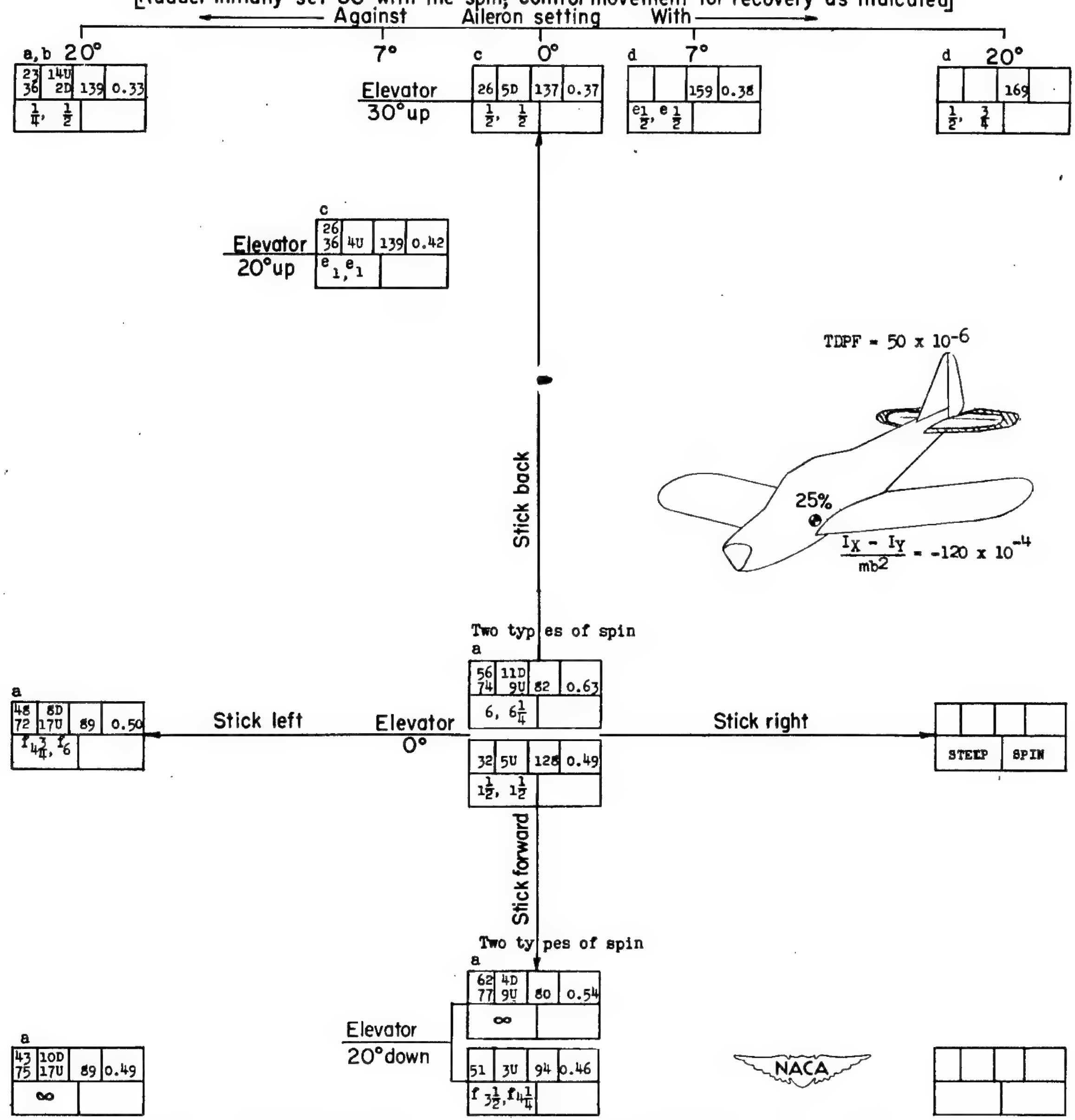
[a]Oscillatory in pitch; range or average values given.
[b]Wandering spin.
[c]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Whipping spin.
[e]Recovery attempted before model reached final steep attitude.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 48.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 48 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]

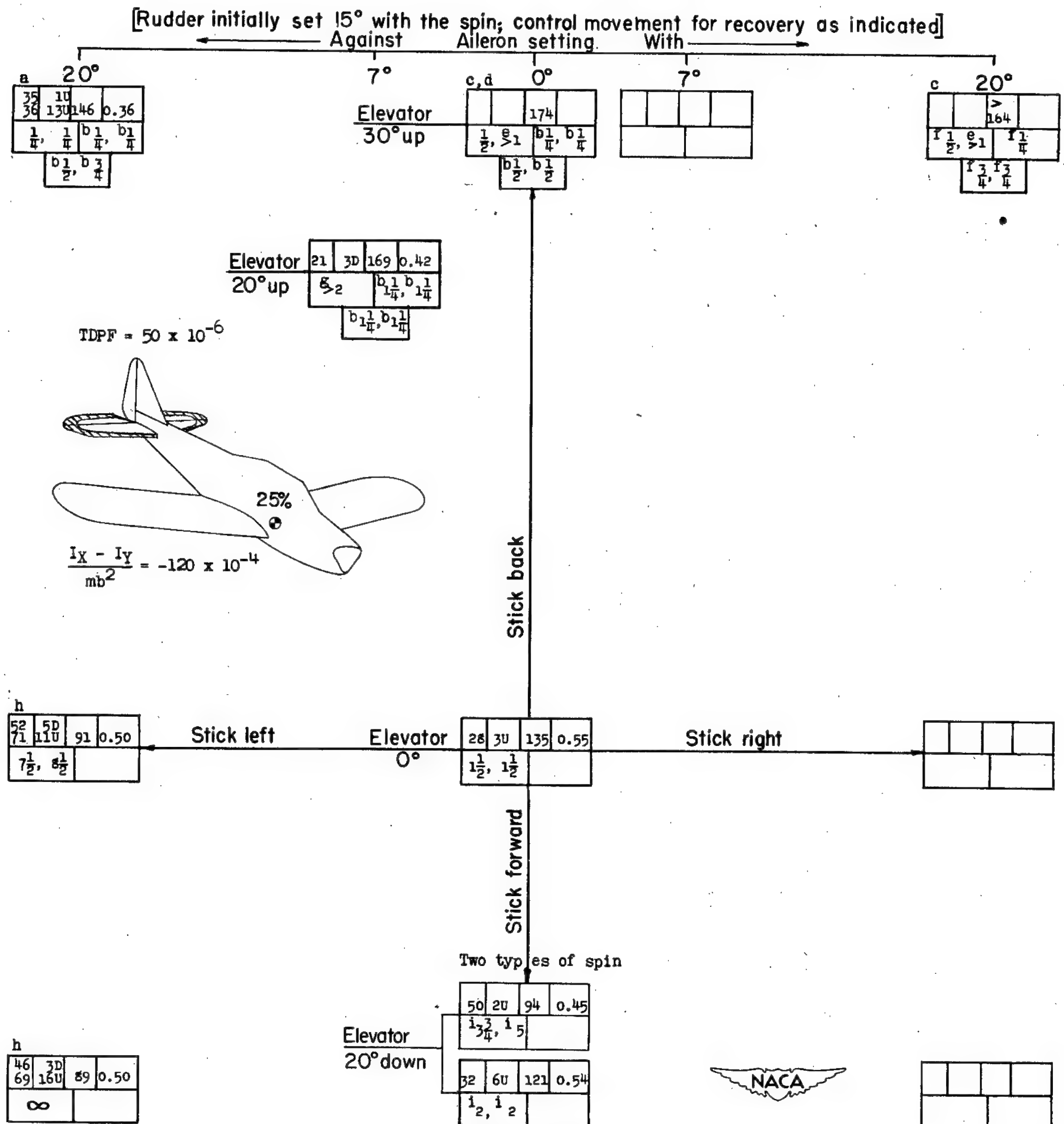


Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

[a]Oscillatory in pitch, roll, and yaw; range or average values given.
[b]Unsteady turning rate about spin axis.
[c]Oscillatory in pitch; range or average values given.
[d]Wandering spin.
[e]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[f]Goes into an inverted glide.

CHART 49.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 49 LISTED IN TABLE III



- [a] Whipping spin.
- [b] Goes into an inverted dive.
- [c] Wandering spin.
- [d] Oscillatory in pitch.
- [e] Approximately $\frac{3}{4}$ turn after rudder reversal, model's attitude became very steep at which time the up elevator caused the model to pull up into a flatter attitude and continue turning to the right.
- [f] Recovery attempted before model reached final steep attitude.
- [g] Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
- [h] Oscillatory in pitch, roll, and yaw; range or average values given.
- [i] Goes into an inverted glide.

Model values converted to corresponding full-scale values.

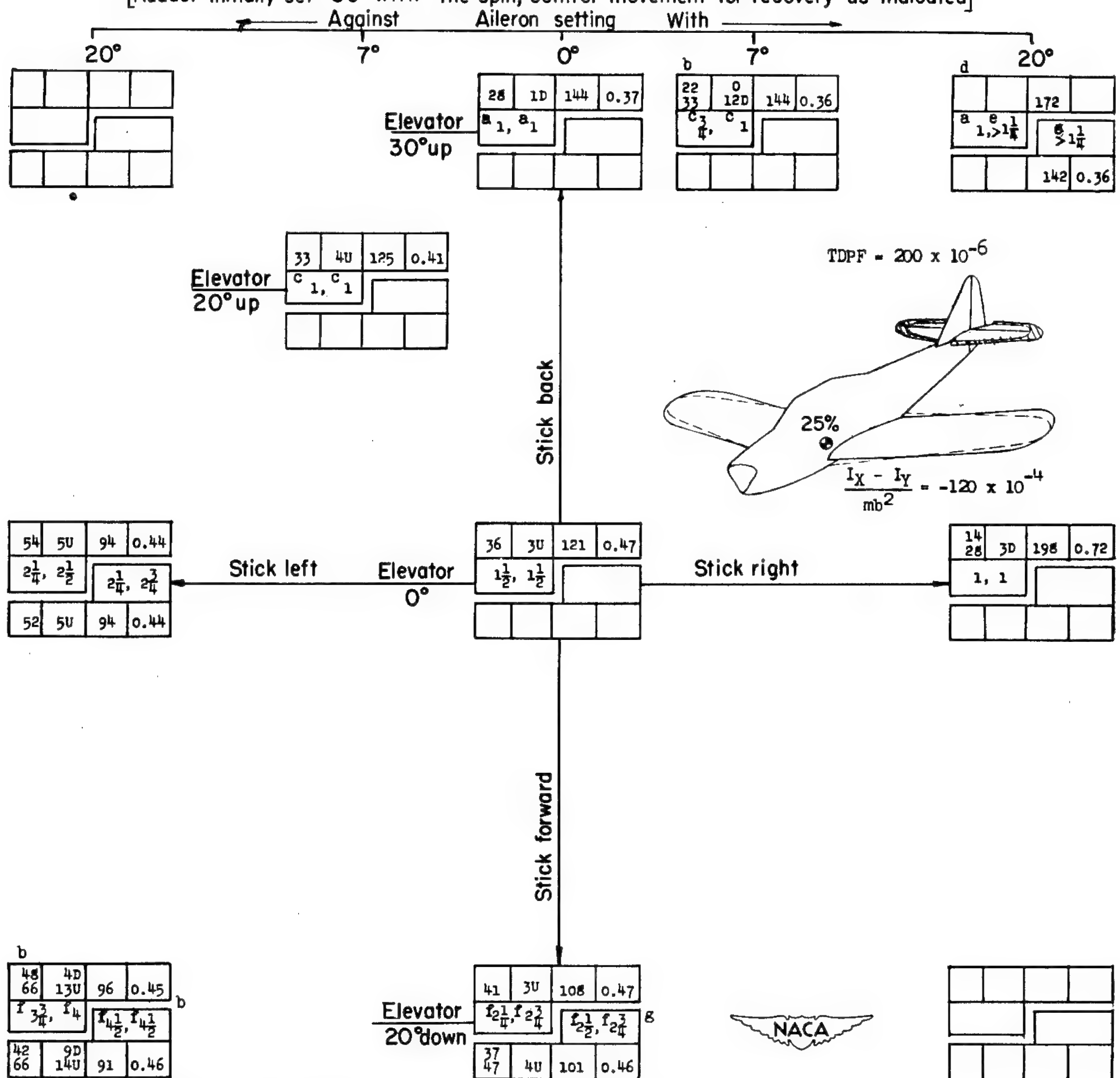
U inner wing up

D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 15° against; Elevator reversed to full down.	
	Turns for recovery: Rudder 15° with to 0°; Elevator neutralized.		

CHART 50.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITIONS 50 AND 70 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



[a]Goes into a slightly turning glide.
[b]Oscillatory in pitch, roll, and yaw; range or average values given.
[c]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Wandering spin.
[e]Approximately one turn after rudder reversal model's attitude became very steep at which time the up elevator caused the model to pull up into a flatter attitude and continue turning to the right.
[f]Goes into an inverted dive.
[g]Oscillatory in pitch; range or average values given.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

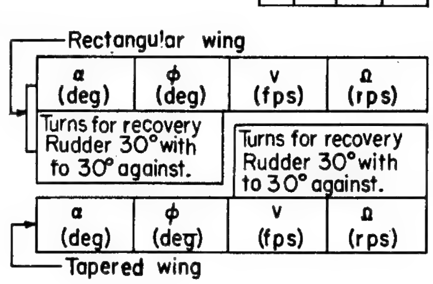
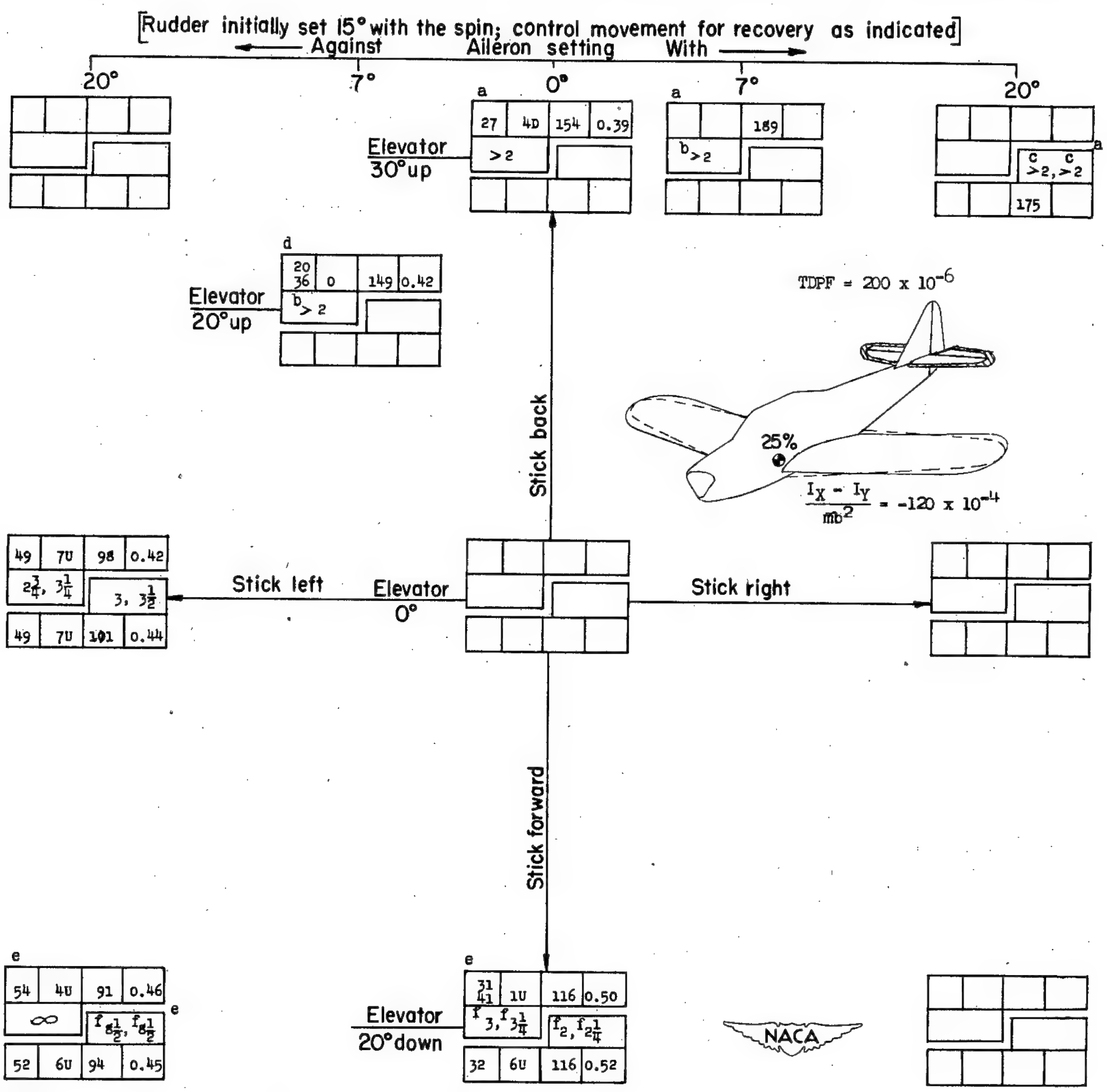


CHART 51.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITIONS 51 AND 71 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



[a]Wandering spin.
[b]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Rudder reversed before model reached its final steep attitude.
[d]Oscillatory in pitch; range or average values given.
[e]Oscillatory in roll and yaw; average values given.
[f]Goes into an inverted glide.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

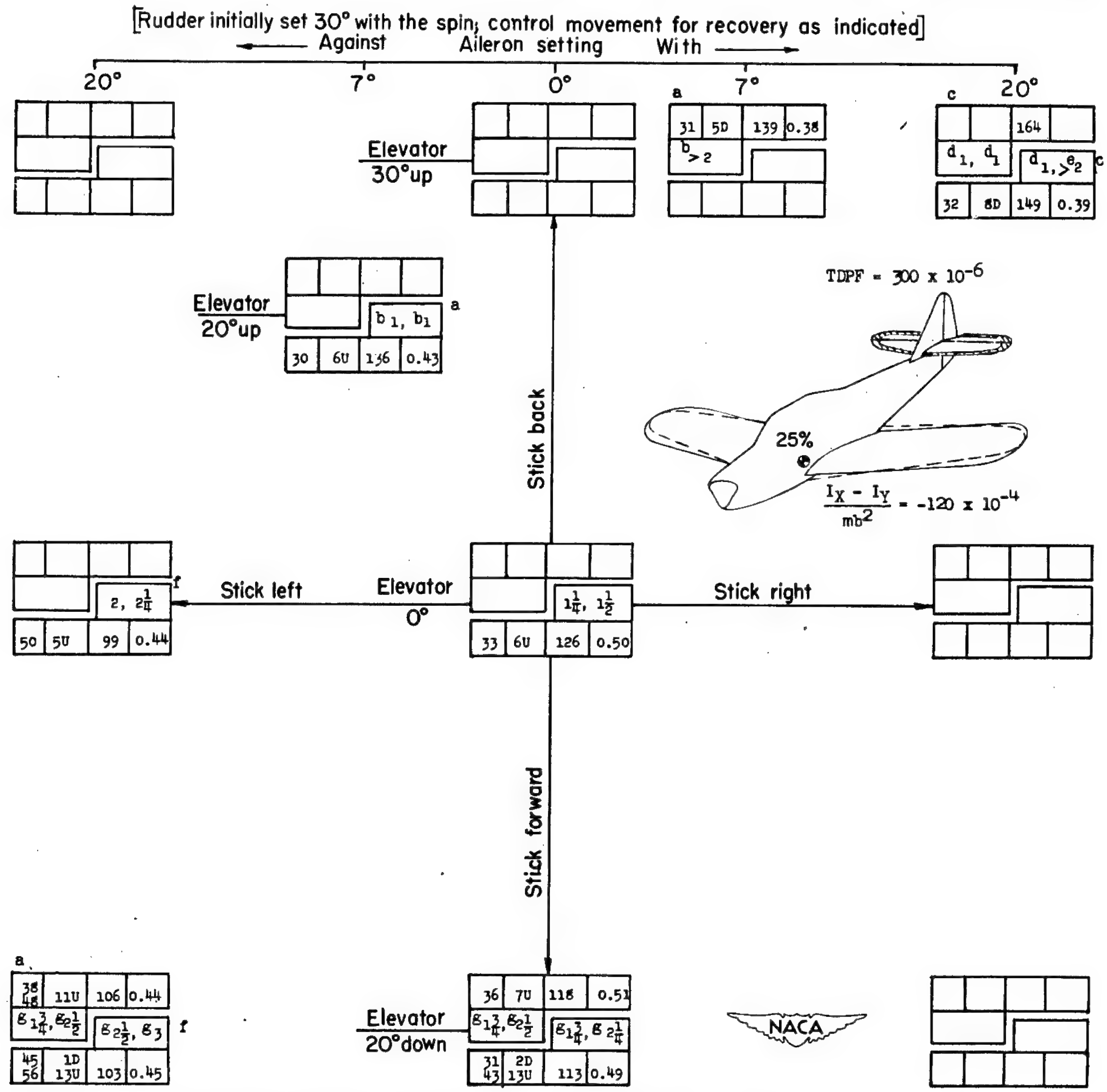
Rectangular wing

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 15° against.	
α (deg)	φ (deg)	V (fps)	Ω (rps)

Tapered wing

CHART 52.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITIONS 52 AND 72 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



[a]Slightly oscillatory in pitch; range or average values given.
[b]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Wanders and has a slight whip.
[d]Goes into a slightly turning glide.
[e]Approximately one turn after rudder reversal model's attitude became very steep at which time the up elevator caused the model to pull up into a flatter attitude and continue to turn to the right.
[f]Oscillatory in roll and yaw; range or average values given.
[g]Goes into an inverted dive.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

Rectangular wing

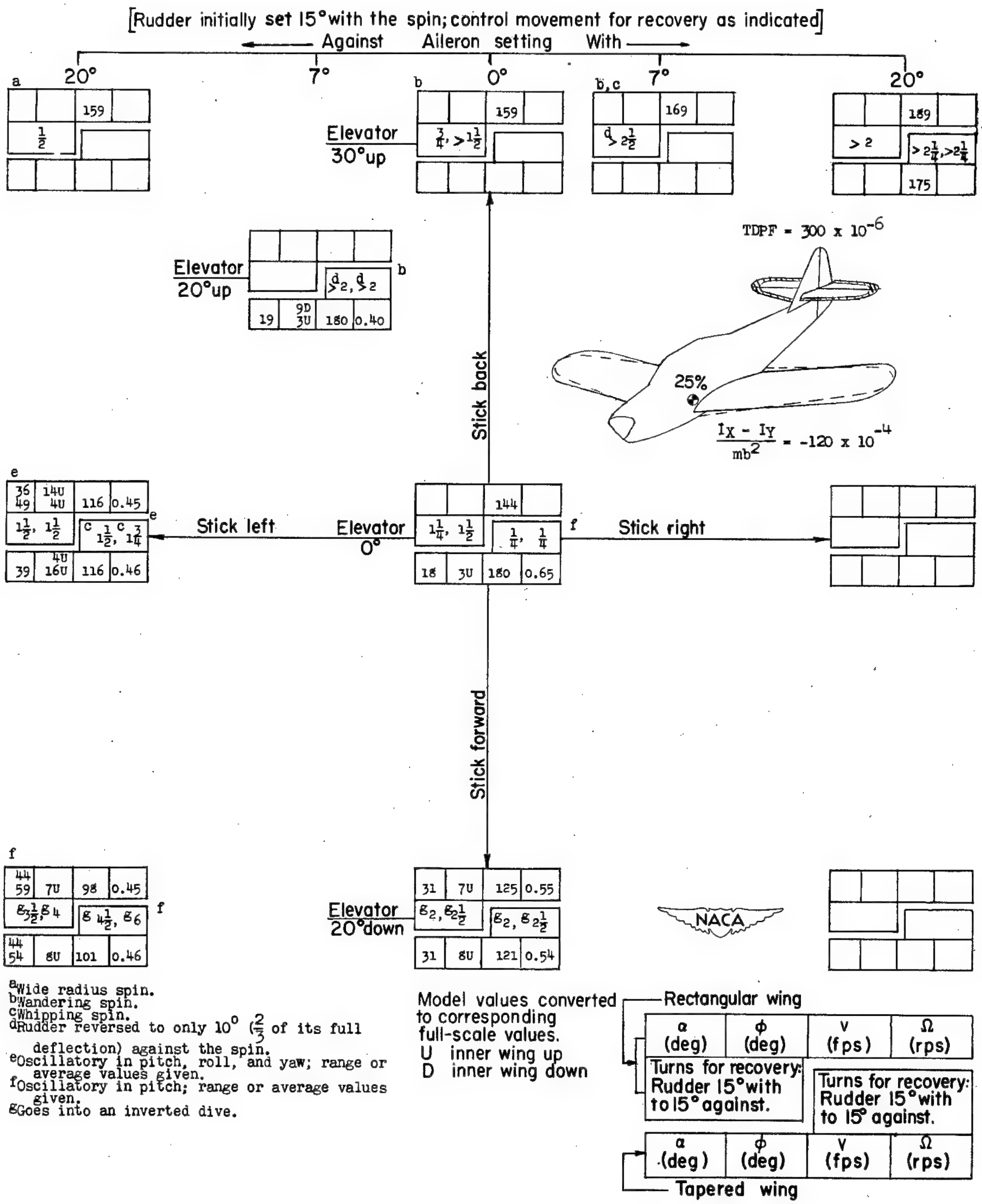
α (deg)	φ (deg)	V (fps)	Ω (rps)

Turns for recovery Rudder 30° with to 30° against. | Turns for recovery Rudder 30° with to 30° against.

α (deg)	φ (deg)	V (fps)	Ω (rps)

Tapered wing

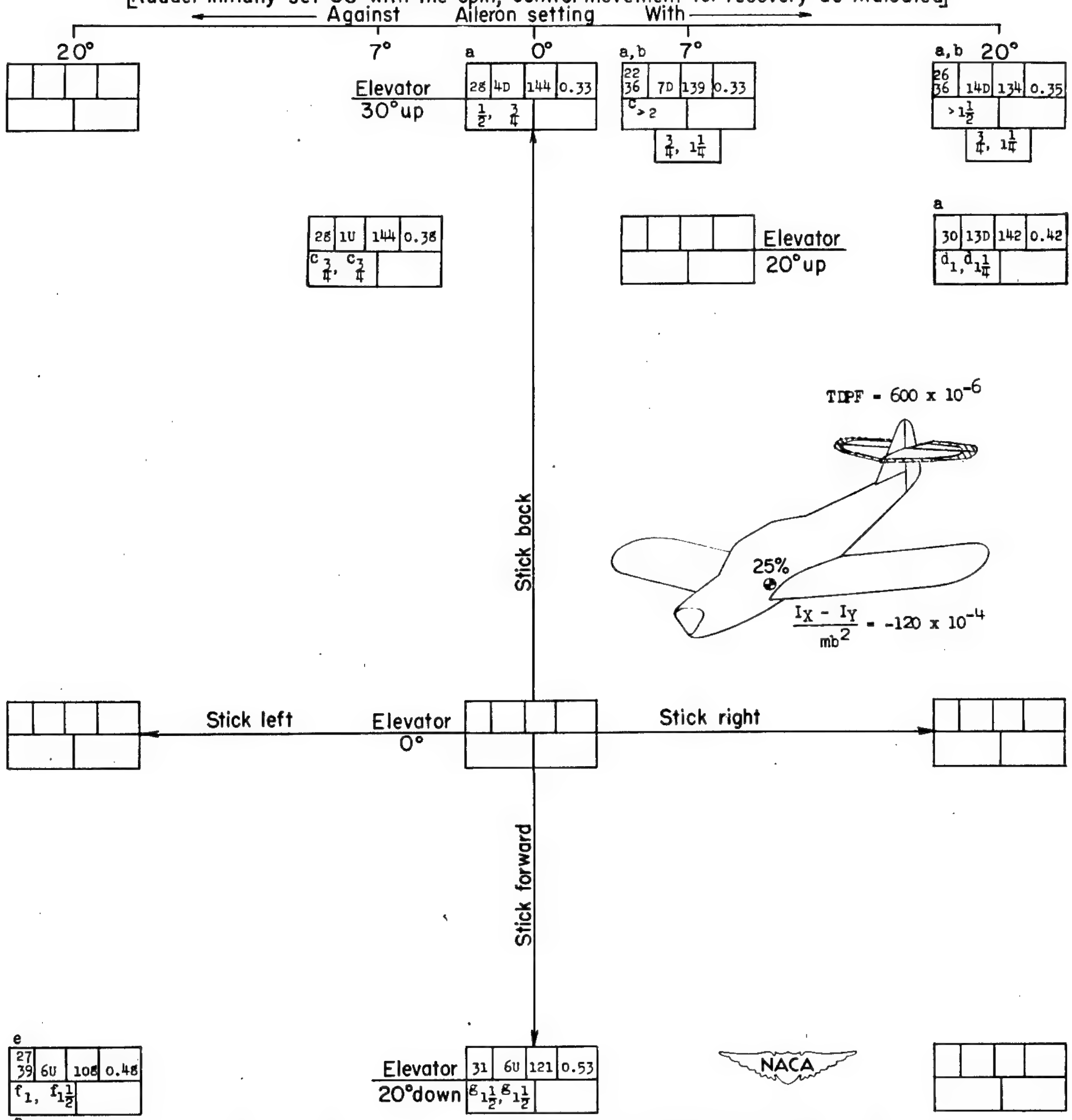
CHART 53.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITIONS 53 AND 73 LISTED IN TABLE III



[a]Wide radius spin.
[b]Wandering spin.
[c]Whipping spin.
[d]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Oscillatory in pitch, roll, and yaw; range or average values given.
[f]Oscillatory in pitch; range or average values given.
[g]Goes into an inverted dive.

CHART 54.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 54 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



[a]Wandering spin.
[b]Oscillatory in pitch; range or average values given.
[c]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Goes into a slightly turning glide.
[e]Oscillatory in pitch, roll, and yaw; range or average values given.
[f]Goes inverted and then goes into erect left spin after recovery from right spin.
[g]Goes into an inverted glide.

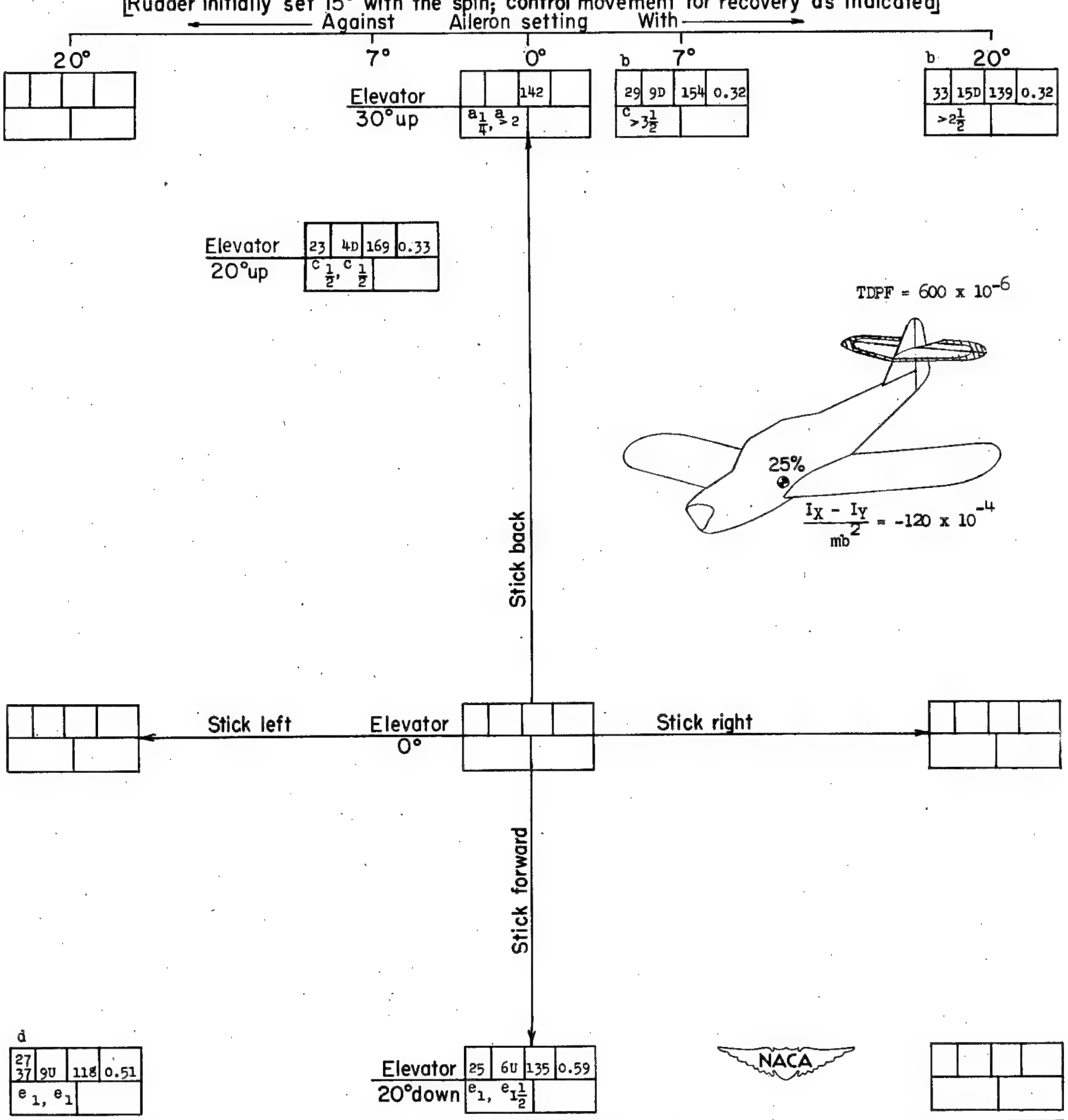
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

Turns for recovery: Rudder 30° with to 30° against, Ailerons neutralized.

CHART 55.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 55 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



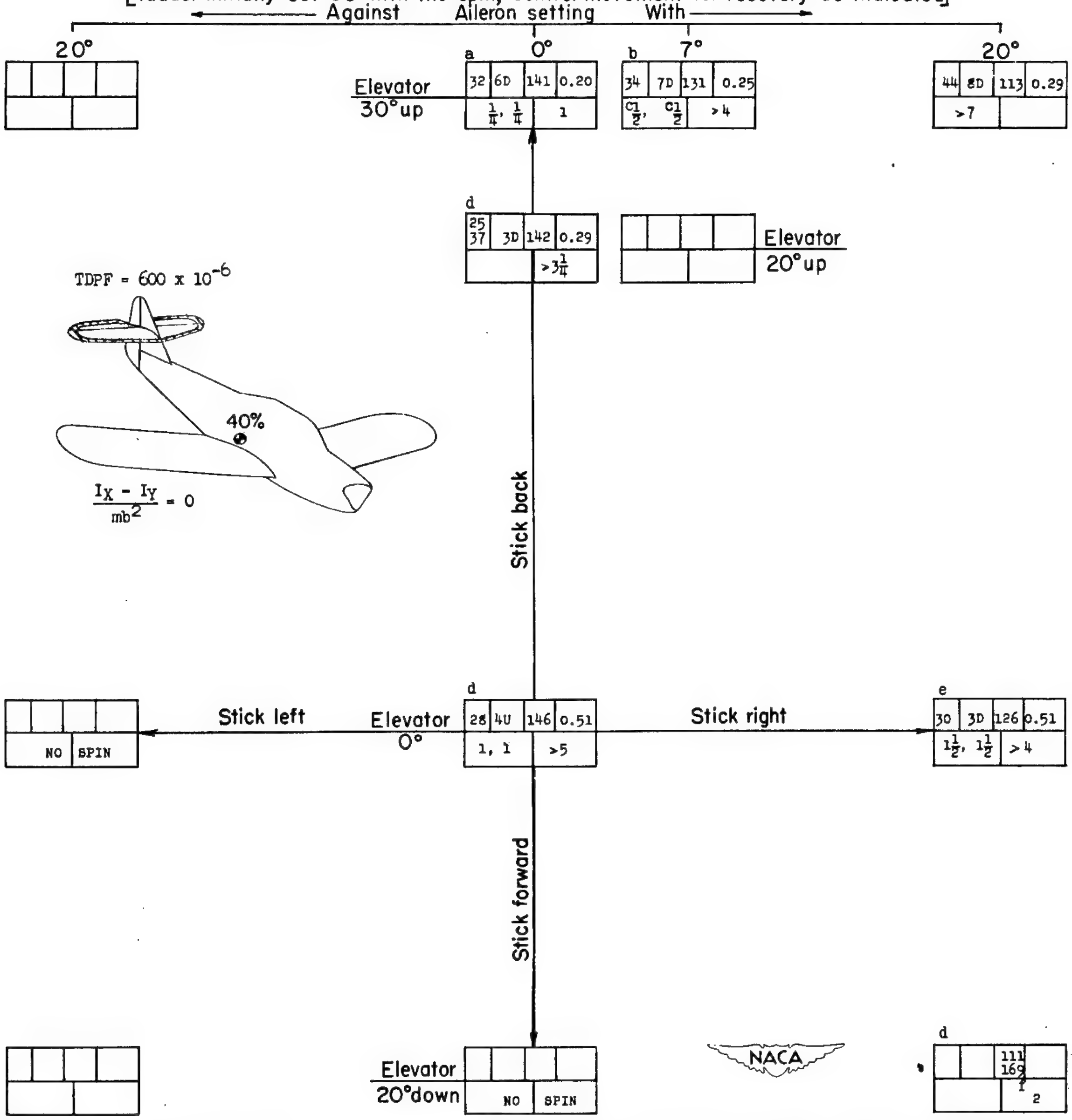
[a]Visual estimate.
[b]Wandering spin.
[c]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Oscillatory in pitch, roll, and yaw; range or average values given.
[e]Goes into an inverted glide.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 56.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 56 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



[a]Wide radius spin with a whip.
[b]Slightly oscillatory in pitch and wanders; average values given.
[c]Rudder reversed to only 20° (2/3 of its full deflection) against the spin.
[d]Oscillates in pitch; range or average values given.
[e]Whipping spin.
[f]Goes into an inverted glide.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 57.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 57 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]

← Against Aileron setting With →

20° | 0° | 7° | 15° | 20°

Elevator 30° up

Aileron	Spin data	Turns for recovery
20° against	(blank)	(blank)
0° [a]	137	$\frac{1}{4}$, $\frac{1}{4}$ / $\frac{3}{4}$
7° with [a]	33, 4D, 139, 0.20	[b]$\frac{1}{2}$, [b]$\frac{1}{2}$
20° with [c]	37–48, 12D, 116–123, 0.27	>13

Elevator 20° up (aileron 7° with): 34, 8D, 135–142, 0.36; >6

Elevator 0°: [c] 23, 1D, 142–156, 0.50; 1, $1\frac{1}{4}$ / >10

Stick left (aileron 20° against, elevator 0°): NO SPIN

Stick right (aileron 20° with, elevator 0°): [c] 24–35, 4D, 131–151, 0.51; >3

Stick back

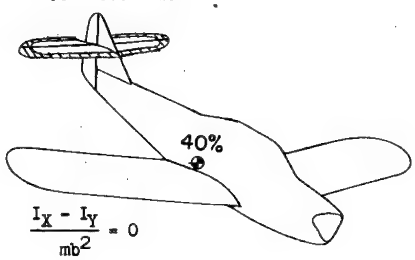
Stick forward

Elevator 20° down (aileron 0°): NO SPIN

Elevator 20° down (aileron 20° with): NO SPIN

Elevator 20° down (aileron 20° against): (blank)

TDPF = 600×10^{-6}



$\frac{I_X - I_Y}{mb^2} = 0$

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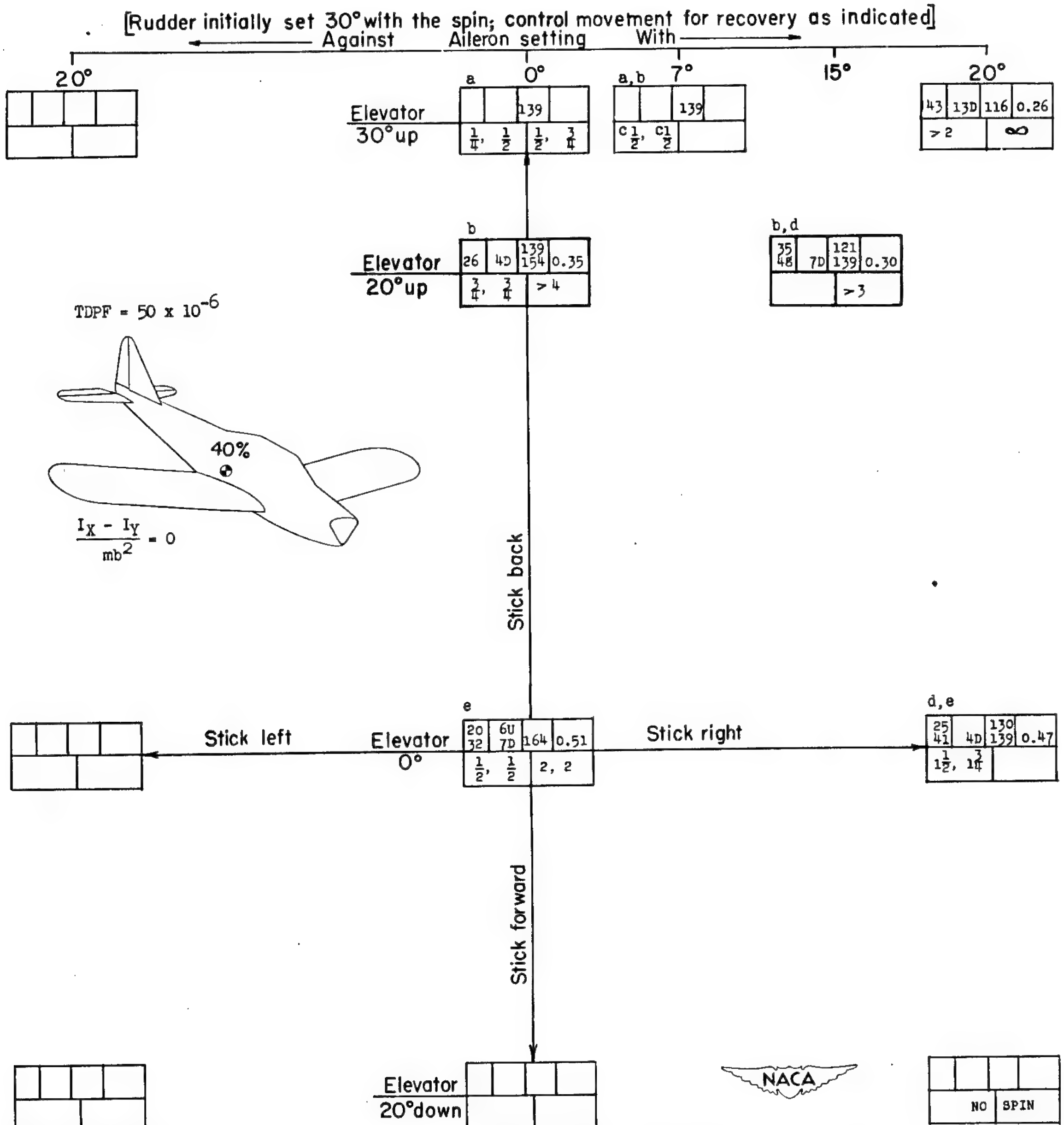
[a]Wide radius spin.
[b]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[c]Oscillatory in pitch; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 58.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 58 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]

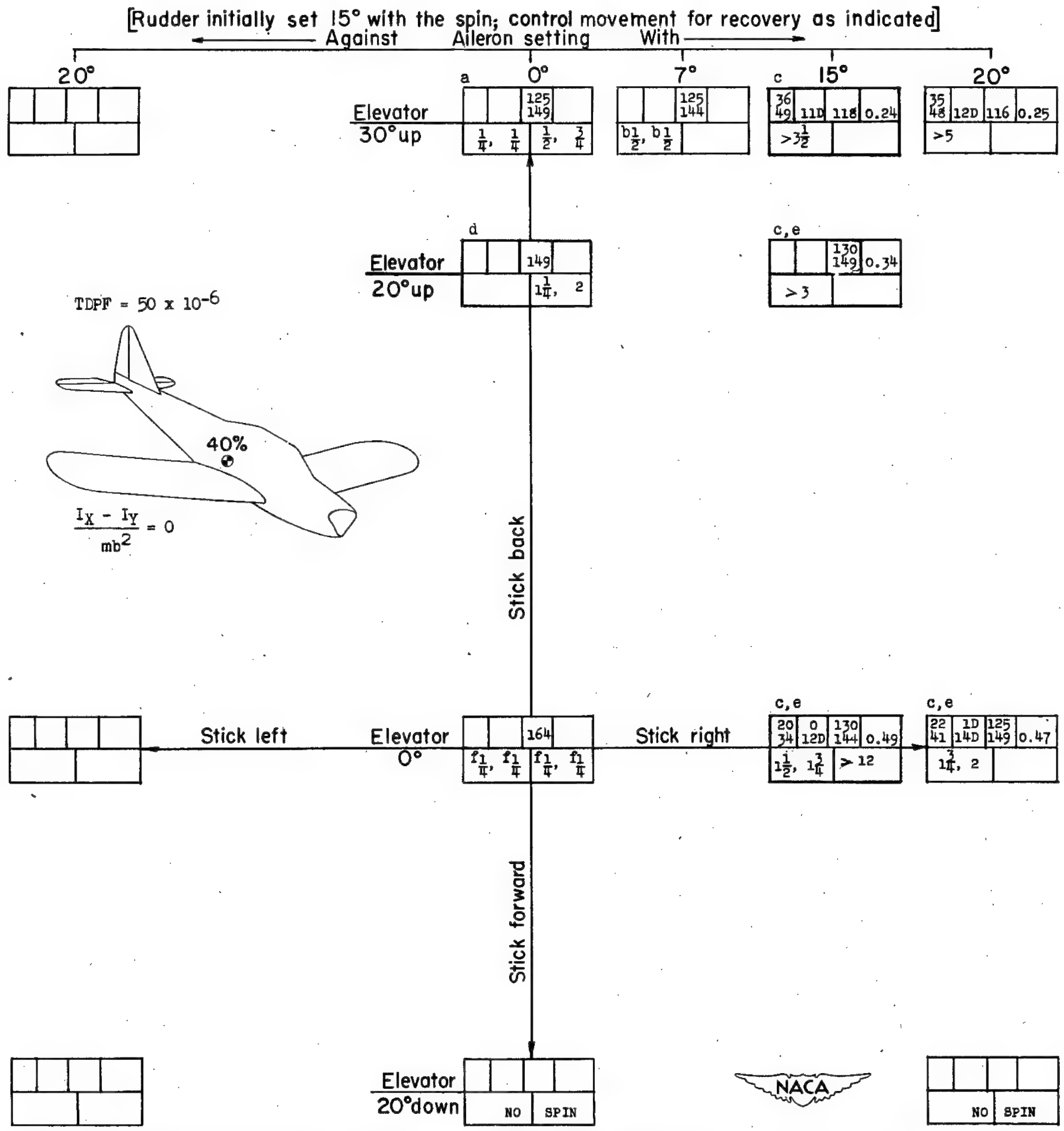


ᵃWide radius spin.
ᵇOscillatory in pitch; range or average values given.
ᶜRudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
ᵈWhipping spin.
ᵉOscillatory in pitch, roll, and yaw; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 59.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 59 LISTED IN TABLE III



[a]Oscillatory in pitch and has a wide radius, range of values given.
[b]Rudder reversed to only 10° (2/3 of its full deflection) against the spin.
[c]Oscillatory in pitch; range or average values given.
[d]Wandering spin.
[e]Whipping spin.
[f]Recovery attempted before model reached final steep attitude.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 60.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 60 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]

← Against — Aileron setting — With →

Elevator 30° up (Stick back)

Aileron setting	α (deg)	φ (deg)	V (fps)	Ω (rps)	Turns for recovery: Rudder 30° with to 30° against	Turns for recovery: Rudder 30° with to 0°
20° against						
0° [a]	26	6D	152	0.39	$b\frac{1}{2}$, $b\frac{1}{2}$	
7° with [a,c]	26–37	7D	144	0.34	$d1$, $d1\frac{1}{4}$	
20° with [c]	37	12D	130	0.32	$b1\frac{1}{2}$, $b2$	

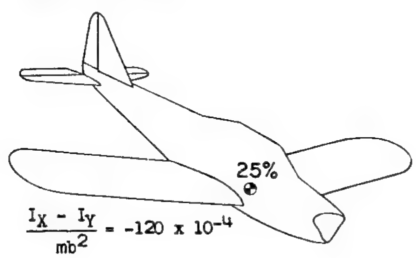
Elevator 0°

Aileron setting	α (deg)	φ (deg)	V (fps)	Ω (rps)	Turns for recovery: Rudder 30° with to 30° against	Turns for recovery: Rudder 30° with to 0°
Stick left						
0°						
Stick right [a]			164		$\frac{3}{4}$	

Elevator 20° down (Stick forward)

Aileron setting	α (deg)	φ (deg)	V (fps)	Ω (rps)	Turns for recovery: Rudder 30° with to 30° against	Turns for recovery: Rudder 30° with to 0°
20° against	34	9U	121	0.48	$e\frac{3}{4}$, $e1$	
0°	30	5U	128	0.51	1, $1\frac{1}{4}$	
20° with						

TDPF = 50×10^{-6}



$\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}$

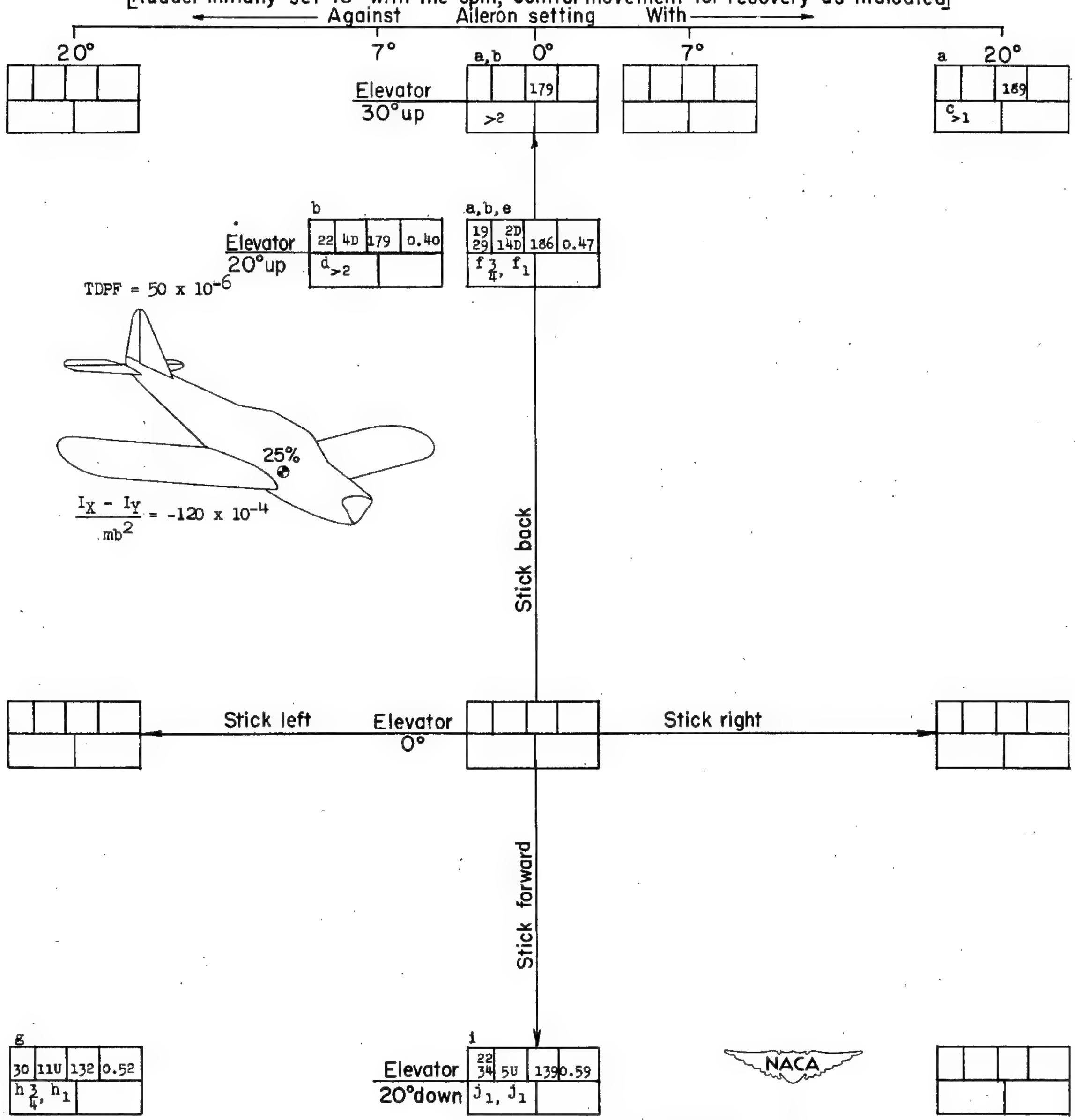
[a]Oscillatory in pitch; range or average values given.
[b]Goes into a slightly turning glide.
[c]Wandering spin.
[d]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin. Goes into a slightly turning glide.
[e]Goes into an inverted glide.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 61.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 61 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



[a]Whipping spin.
[b]Wandering spin.
[c]Recovery attempted before model reached final steep attitude.
[d]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Oscillatory in pitch, roll, and yaw; range or average values given.
[f]Goes into a slightly turning glide.
[g]Slightly oscillatory in roll and yaw; average values given.
[h]Goes into a left spin after recovery from right spin.
[i]Slightly oscillatory in pitch; range or average values given.
[j]Goes into an inverted glide.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 62.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 62 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]

Aileron setting: ← Against — With →

Aileron 20° against, elevator 30° up: no data.

Aileron 7° against, elevator 30° up: no data.

Elevator 30° up, aileron 0°, spin [a]:

α (deg)	φ (deg)	V (fps)	Ω (rps)
		149	
$\frac{3}{4}$, 1			

Elevator 30° up, aileron 7° with, spin [b]:

α (deg)	φ (deg)	V (fps)	Ω (rps)
		164	
[c]$>2\frac{1}{4}$			

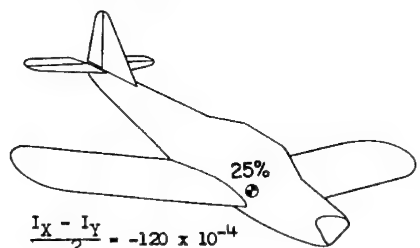
Elevator 30° up, aileron 20° with, spin [a,b]:

α (deg)	φ (deg)	V (fps)	Ω (rps)
		164	
$>2\frac{1}{2}$			

Elevator 20° up, aileron 0°:

α (deg)	φ (deg)	V (fps)	Ω (rps)
22	2D	159	0.42
[c]$\frac{1}{2}$, [c]$\frac{3}{4}$			

TDPF = 100×10^{-6}



$\frac{I_X - I_Y}{mb^2} = -120 \times 10^{-4}$

Stick back

Elevator 0°: aileron 0°, 20° against (stick left) and 20° with (stick right): no data.

Stick left — Stick right

Stick forward

Elevator 20° down, aileron 0°:

α (deg)	φ (deg)	V (fps)	Ω (rps)
26	5U	139	0.57
$\frac{1}{4}$, $\frac{3}{4}$			

Elevator 20° down, aileron 20° against, [d]:

α (deg)	φ (deg)	V (fps)	Ω (rps)
22 / 33	9U	128	0.49
$\frac{1}{2}$, $\frac{3}{4}$			

Elevator 20° down, aileron 20° with: no data.

[a]Wandering spin.
[b]Whipping spin.
[c]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Oscillatory in pitch, roll, and yaw; range or average values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

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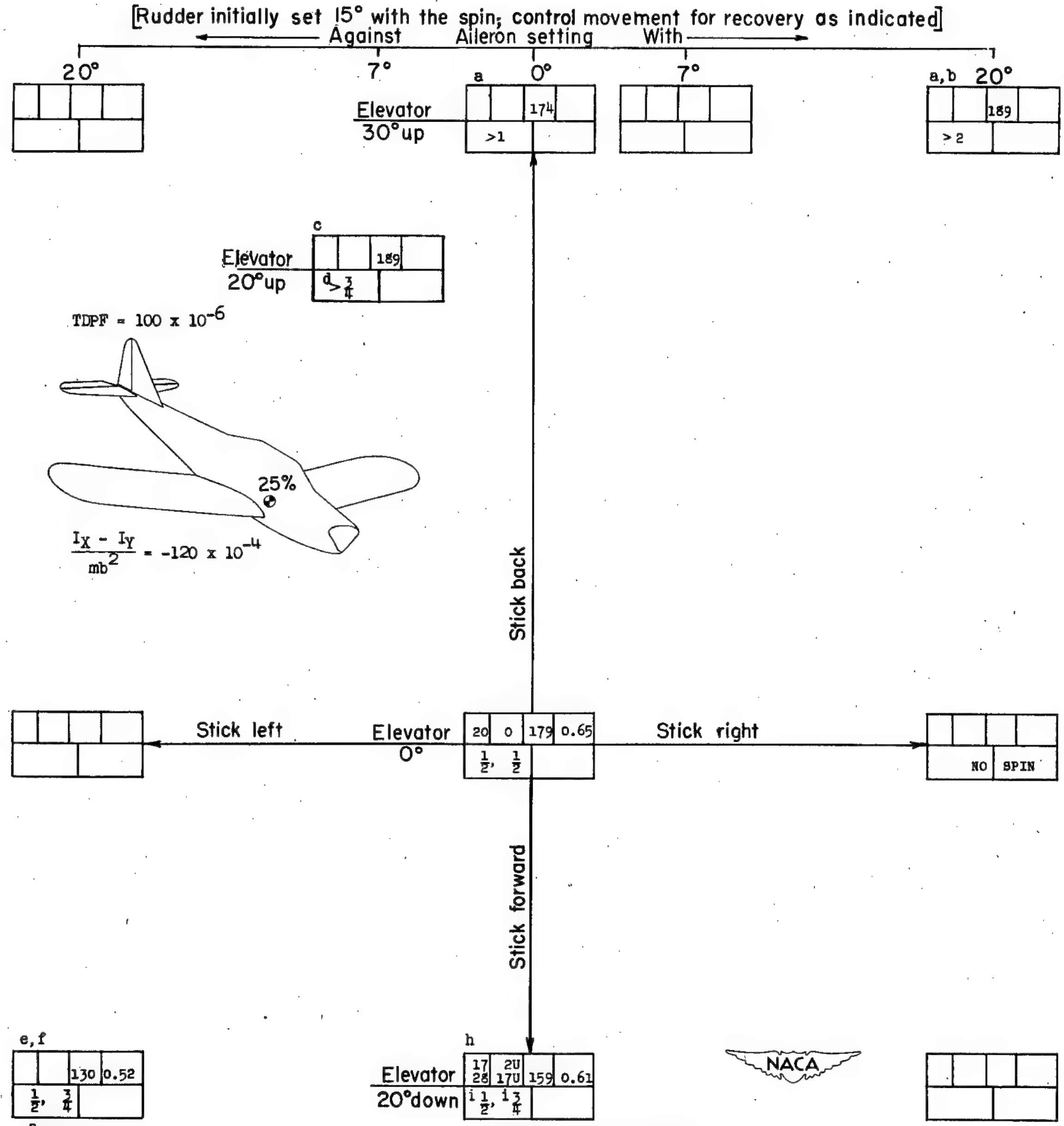
CHART 63.- SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 63 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]

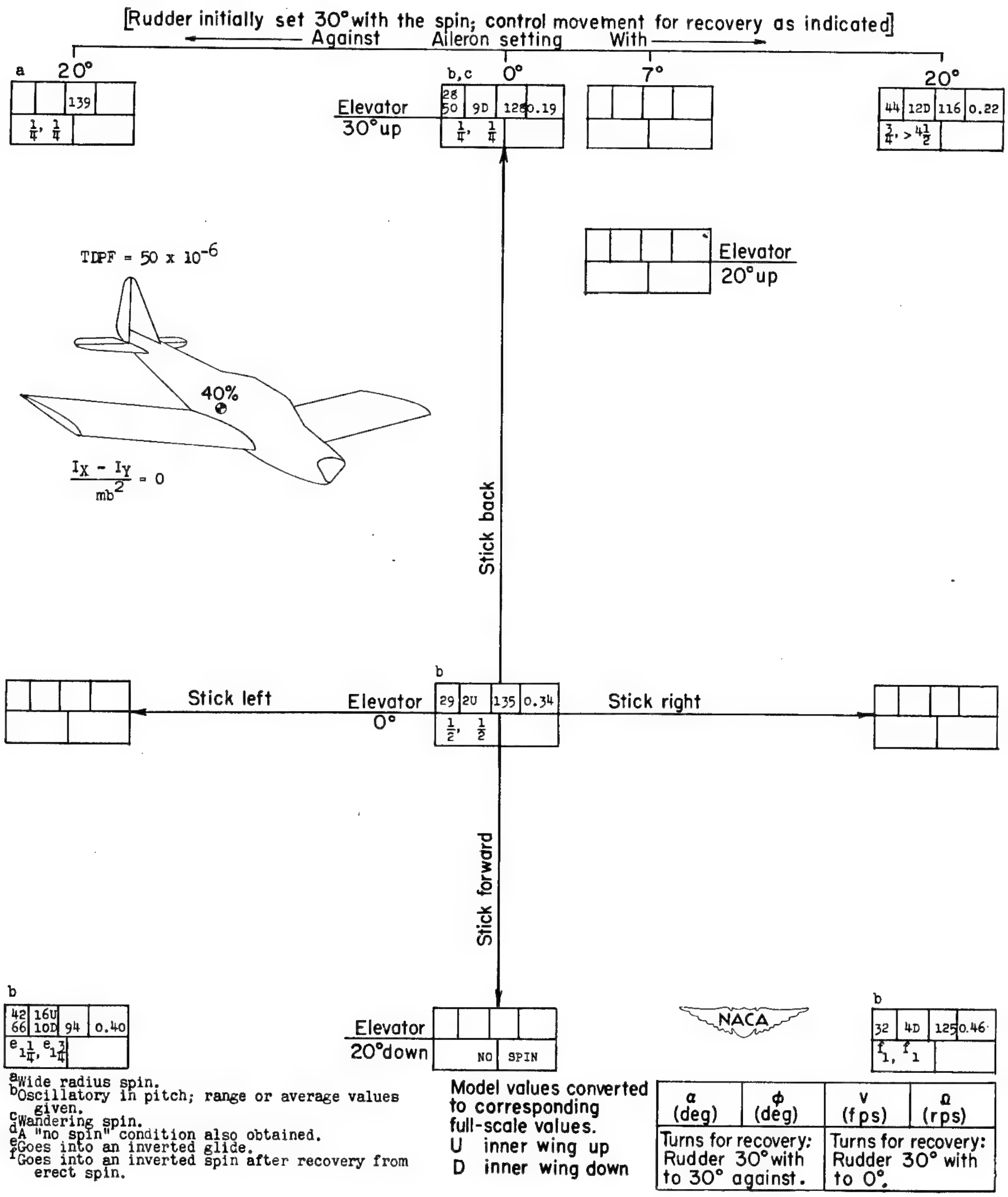


[a]Wandering spin.
[b]Whipping spin.
[c]Wide radius spin.
[d]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Oscillatory in roll and yaw.
[f]A "no spin" condition also obtained.
[g]Goes inverted and then goes into a left erect spin after recovery from a right spin.
[h]Oscillatory in pitch, roll, and yaw; range or average values given.
[i]Goes into an inverted dive.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

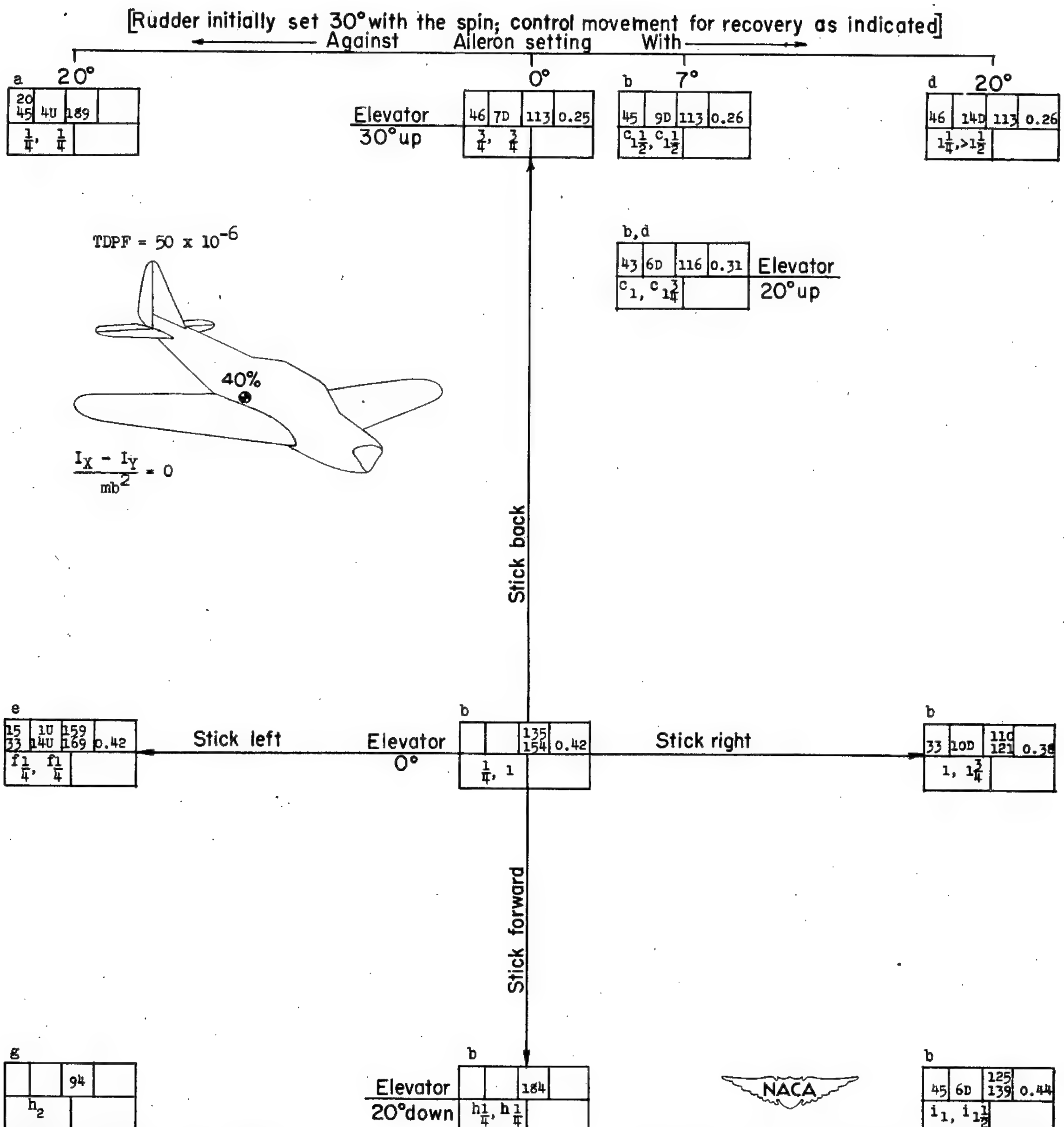
α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

CHART 64.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 64 LISTED IN TABLE III



[a]Wide radius spin.
[b]Oscillatory in pitch; range or average values given.
[c]Wandering spin.
[d]A "no spin" condition also obtained.
[e]Goes into an inverted glide.
[f]Goes into an inverted spin after recovery from erect spin.

CHART 65.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 66 LISTED IN TABLE III



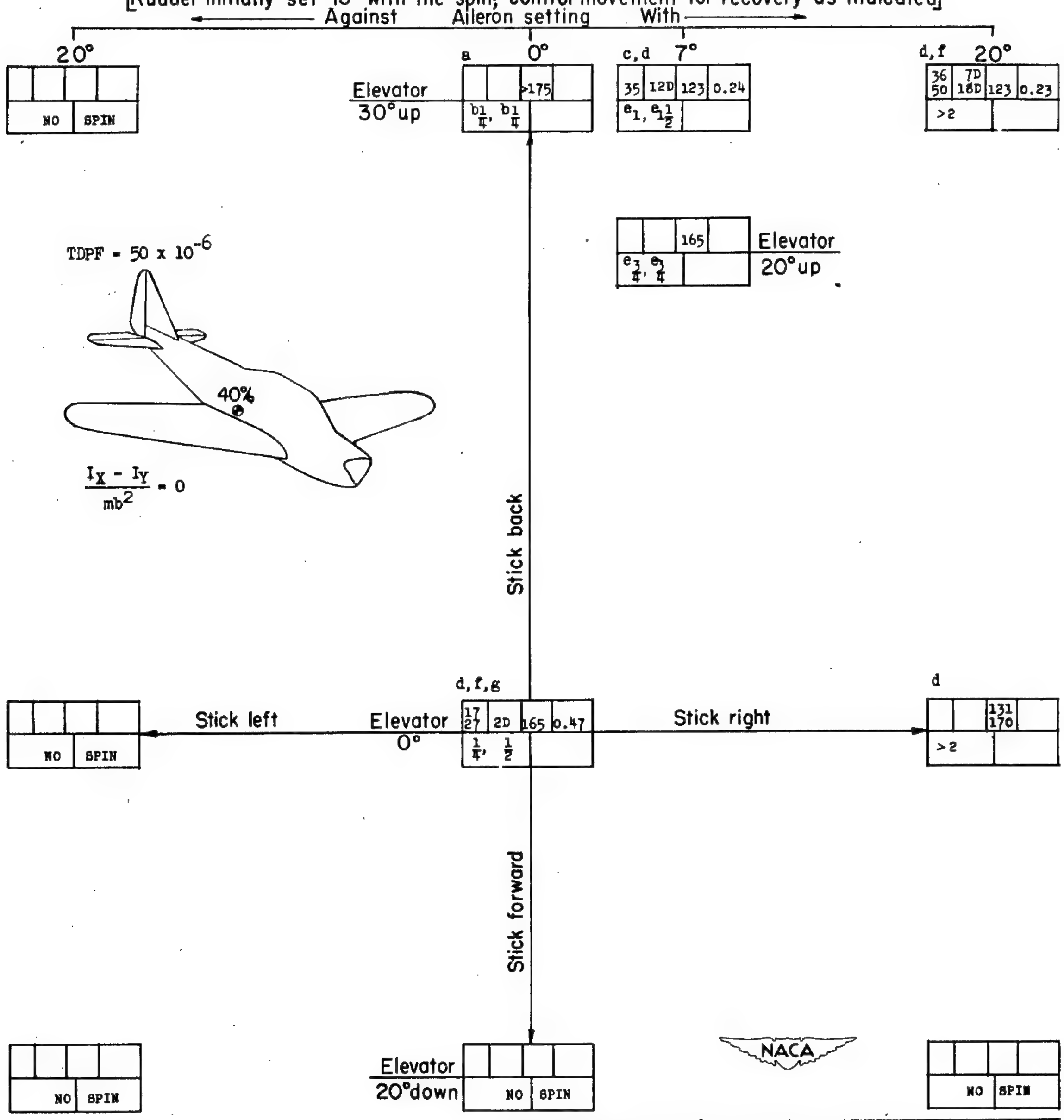
[a]Wide radius spin with a whip.
[b]Oscillatory in pitch; range or average values given.
[c]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[d]Wandering spin.
[e]Oscillatory in pitch, roll, and yaw; range of values given.
[f]Goes into a left spin after recovery from right spin.
[g]A "no spin" condition also obtained.
[h]Goes into an inverted glide.
[i]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

CHART 66.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 67 LISTED IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated]



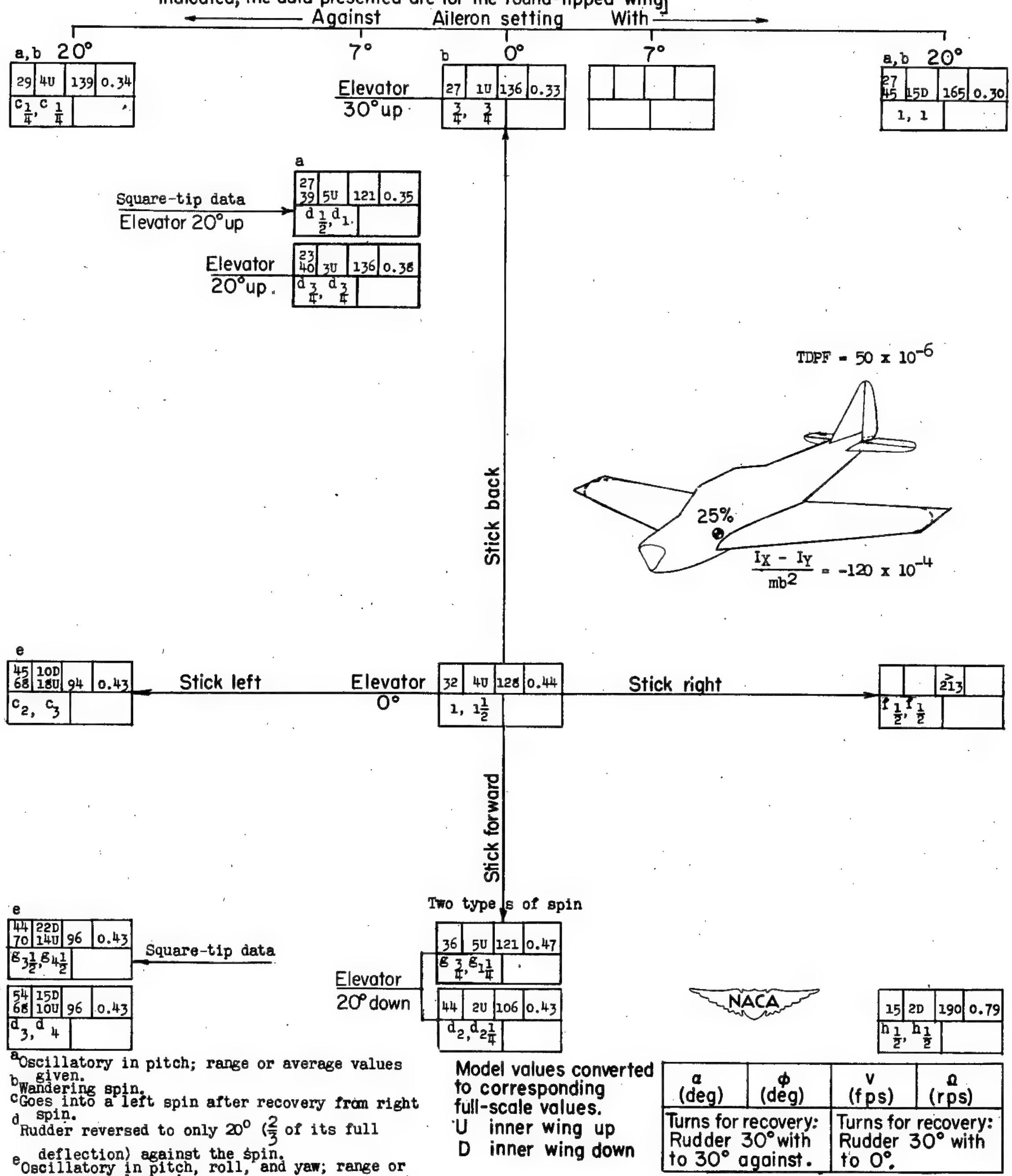
[a]Wide radius spin.
[b]Recovery attempted before model reached final steep attitude.
[c]A steeper type spin also obtained.
[d]Oscillatory in pitch; range or average values given.
[e]Rudder reversed to only 10° ($\frac{2}{3}$ of its full deflection) against the spin.
[f]Wandering spin.
[g]Whipping spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

Chart 67.-SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITIONS 68 AND 75 LISTED IN TABLE III

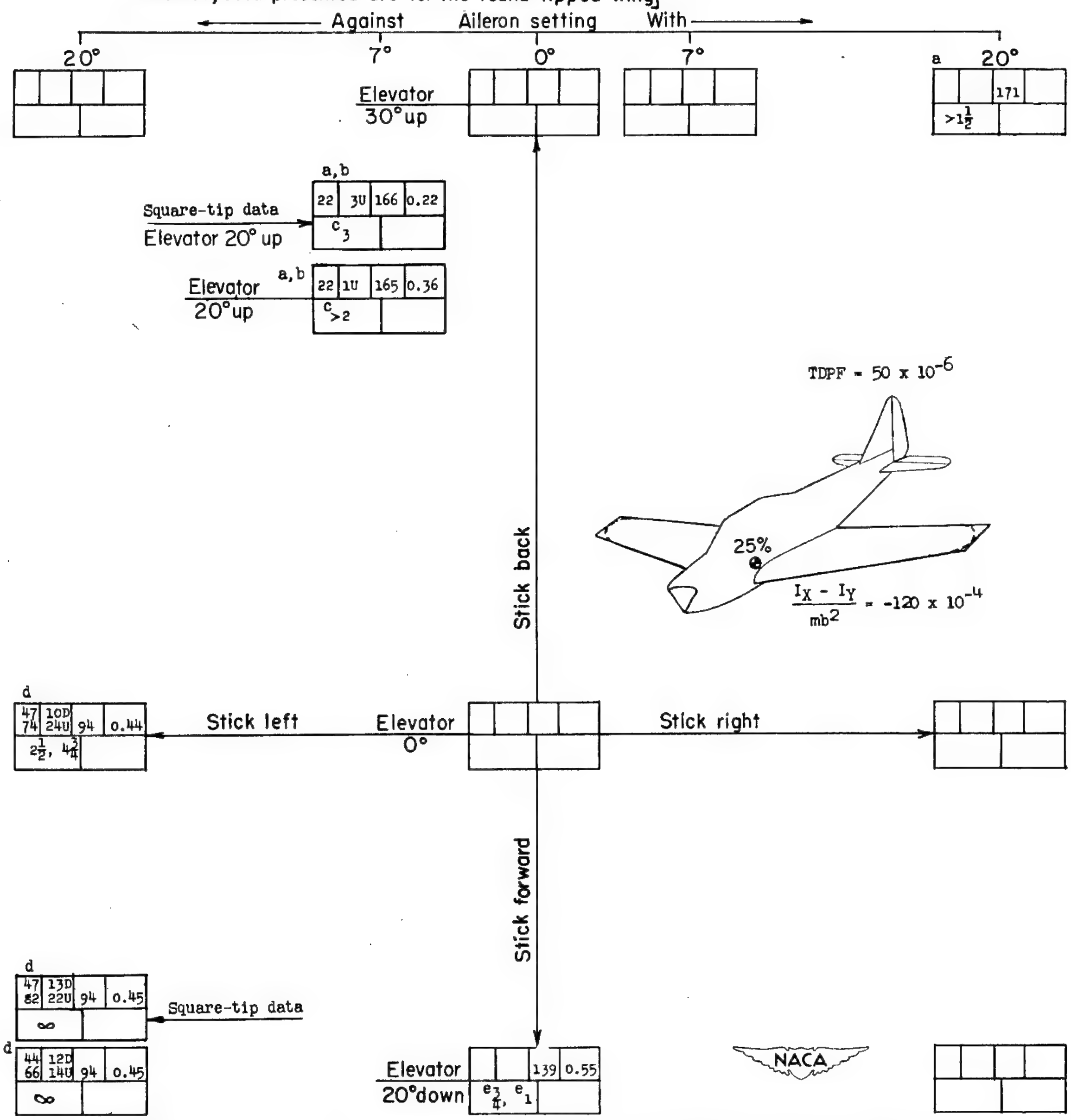
[Rudder initially set 30° with the spin; control movement for recovery as indicated; unless otherwise indicated, the data presented are for the round-tipped wing]



[a]Oscillatory in pitch; range or average values given.
[b]Wandering spin.
[c]Goes into a left spin after recovery from right spin.
[d]Rudder reversed to only 20° ($\frac{2}{3}$ of its full deflection) against the spin.
[e]Oscillatory in pitch, roll, and yaw; range or average values given.
[f]Visual estimate.
[g]Goes into an inverted glide.
[h]Goes into an inverted spin after recovery from erect spin.

CHART 68.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITIONS 69 AND 76 IN TABLE III

[Rudder initially set 15° with the spin; control movement for recovery as indicated; unless otherwise indicated, data presented are for the round-tipped wing]



Model values converted to corresponding full-scale values.

U inner wing up

D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 15° with to 15° against.		Turns for recovery: Rudder 15° with to 0°.	

[a]Wandering spin.

[b]Oscillatory in pitch; average values given.

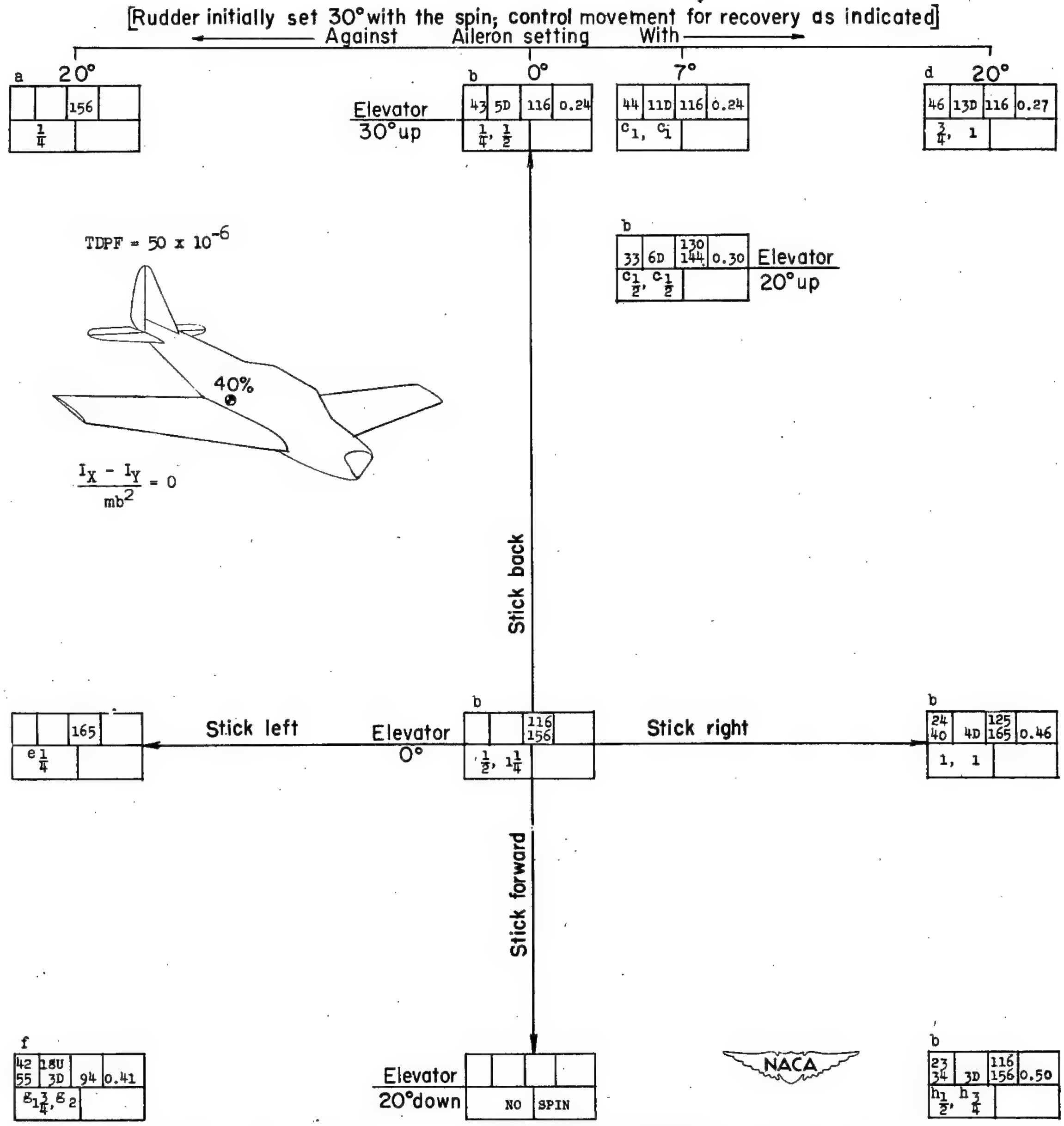
[c]Rudder reversed to only 10° (⅔ of its full deflection) against the spin.

[d]Oscillatory in pitch, roll, and yaw; range or average values given.

[e]Goes into an inverted glide.

CHART 69.–SPIN AND RECOVERY CHARACTERISTICS OF MODEL FOR TEST CONDITION 74 LISTED IN TABLE III

[Rudder initially set 30° with the spin; control movement for recovery as indicated]



[a]Wide radius spin.
[b]Oscillatory in pitch; range or average values given.
[c]Rudder reversed to only 20° (2/3 of its full deflection) against the spin.
[d]Wanders slightly and has a slight whip.
[e]Goes inverted then enters a left erect spin after recovery from right spin.
[f]Oscillatory in pitch, roll, and yaw; range or average values given.
[g]Goes into an inverted glide.
[h]Goes into an inverted spin after recovery from erect spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)	V (fps)	Ω (rps)
Turns for recovery: Rudder 30° with to 30° against.		Turns for recovery: Rudder 30° with to 0°.	

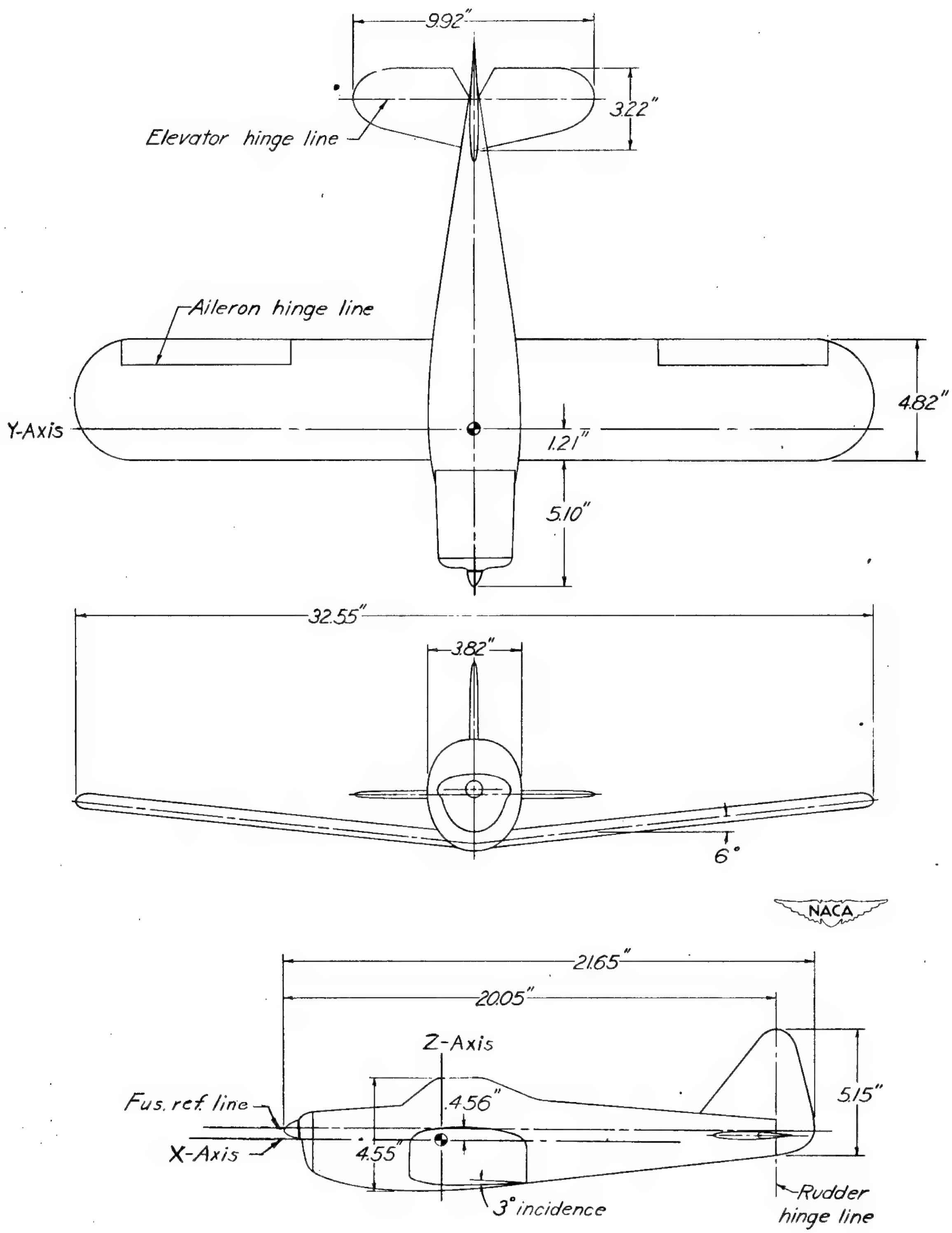


Figure 1.- Three-view drawing of model with tail 1a installed. Center-of-gravity position, 25 percent $\bar{c}$.

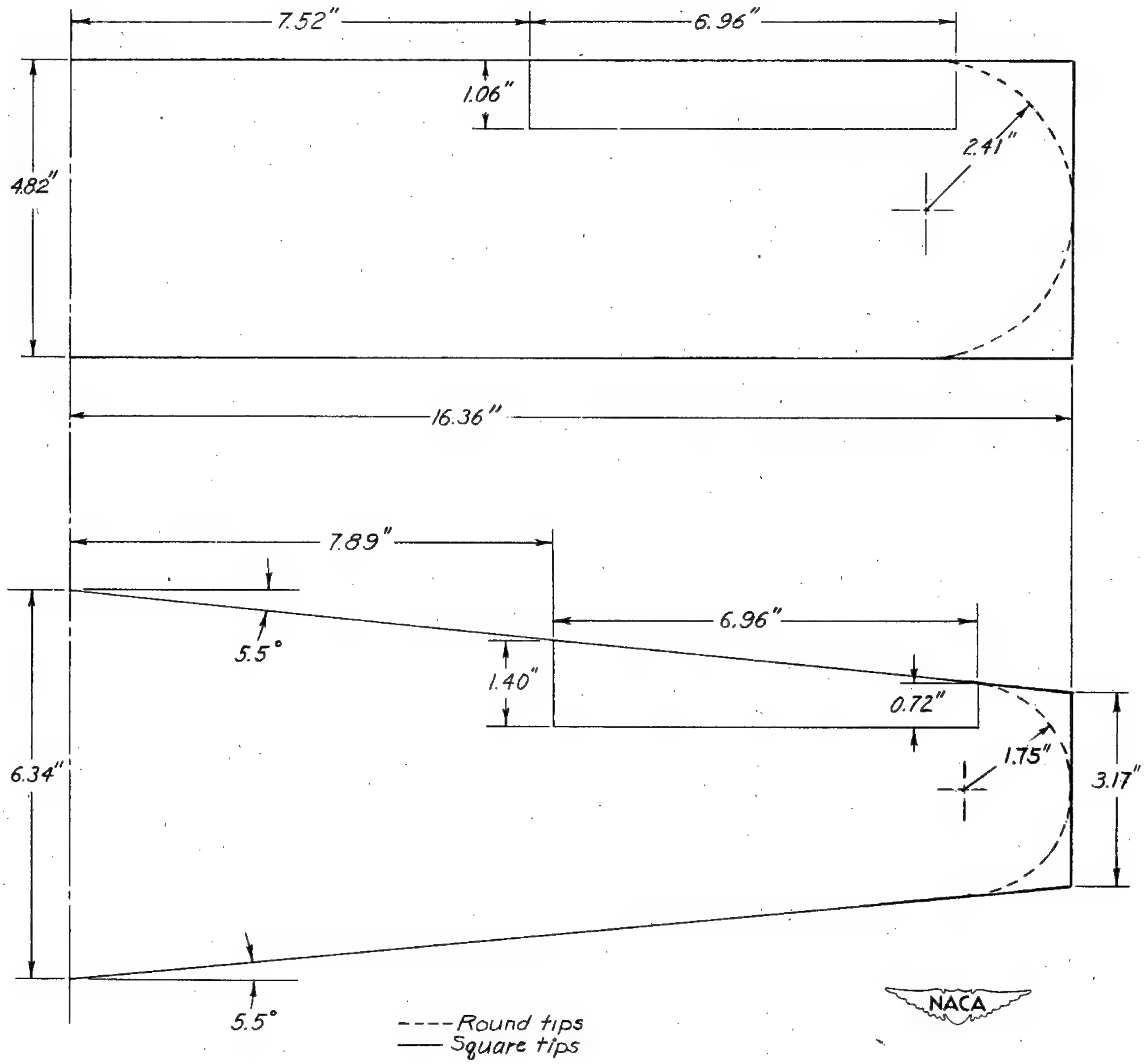


Figure 2.- Comparison of the wing plan forms tested on the model.

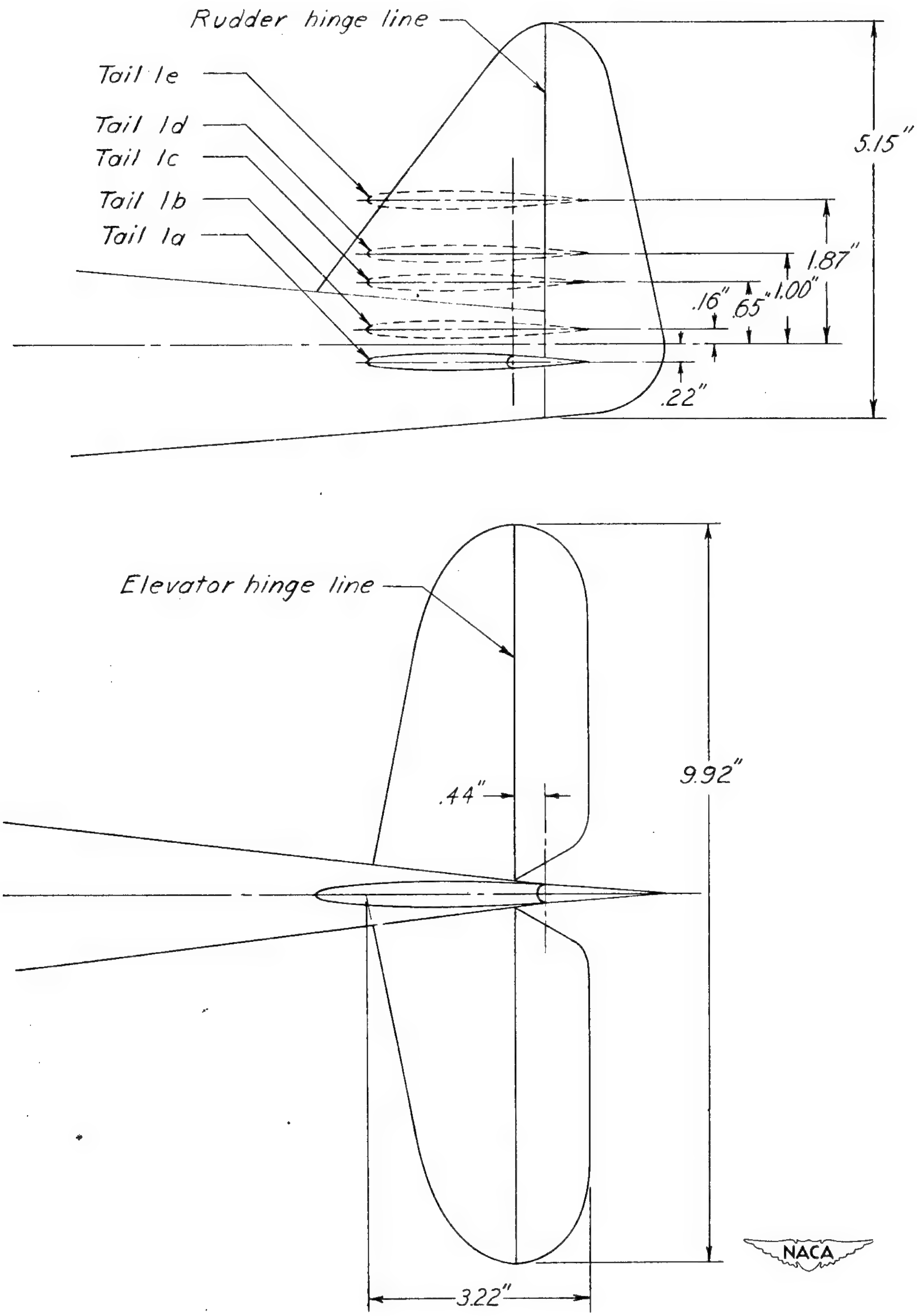


Figure 3.- The 1-series tails (normal tail) tested on the model.

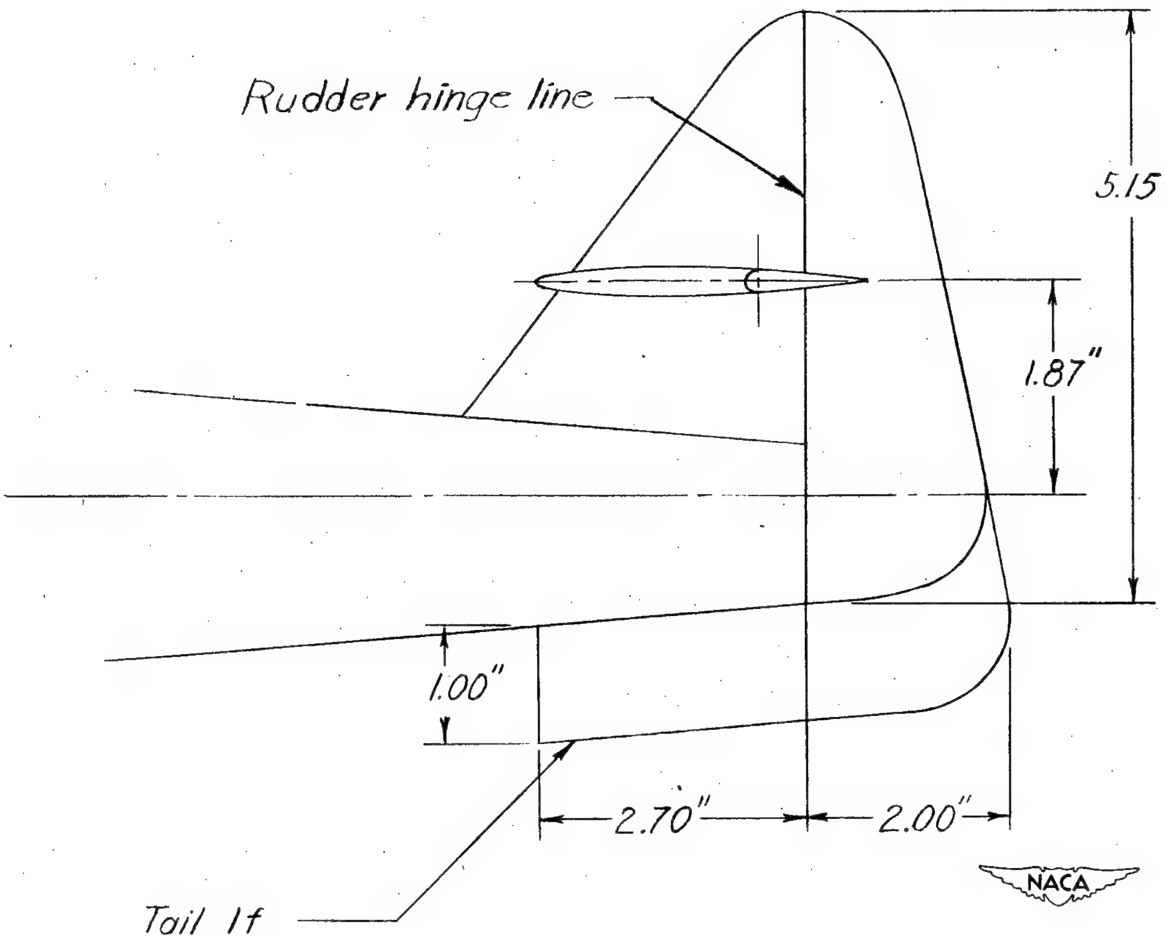


Figure 3.- Concluded.

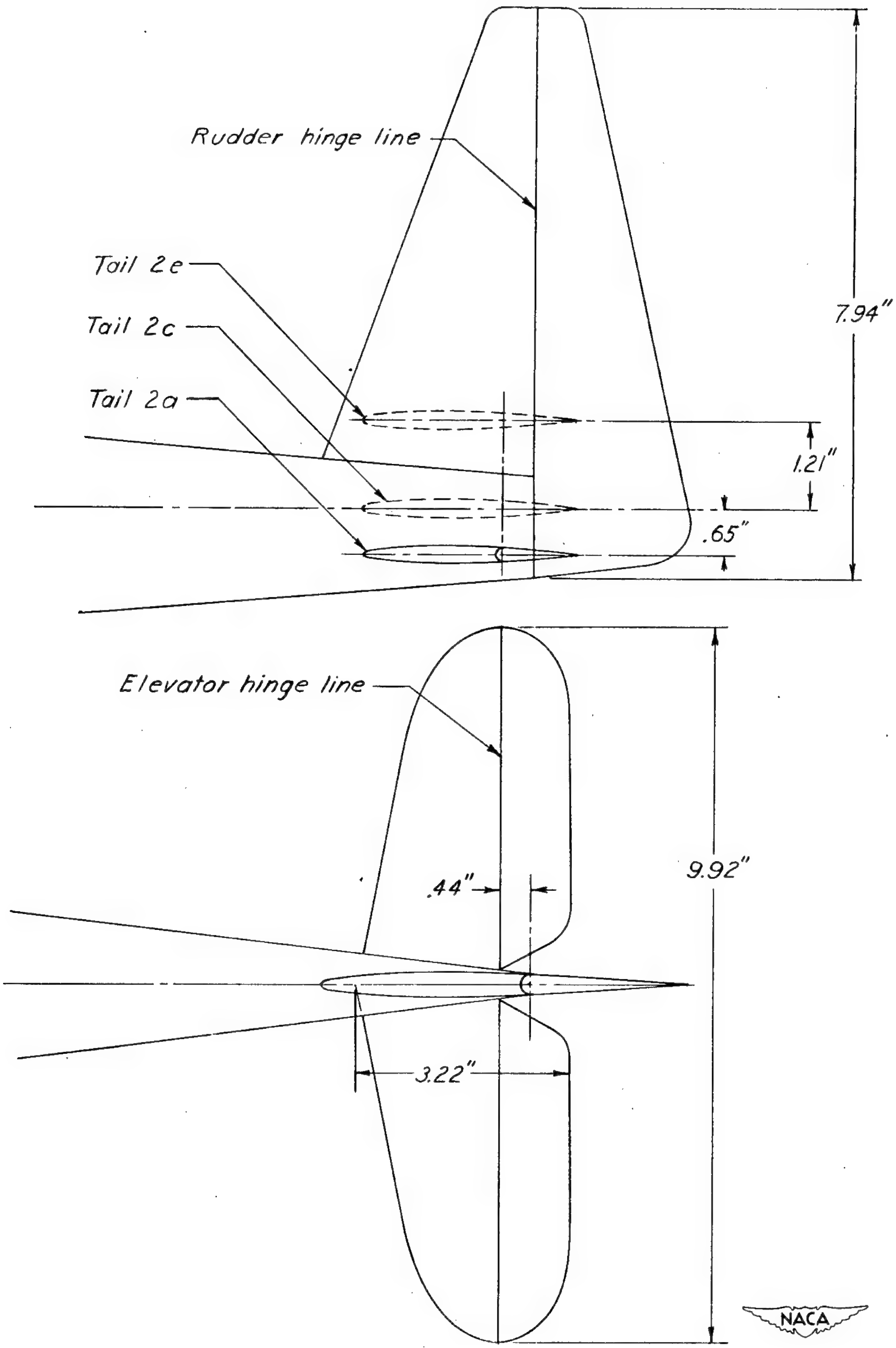


Figure 4.- The 2-series tails (large vertical tail) tested on the model.

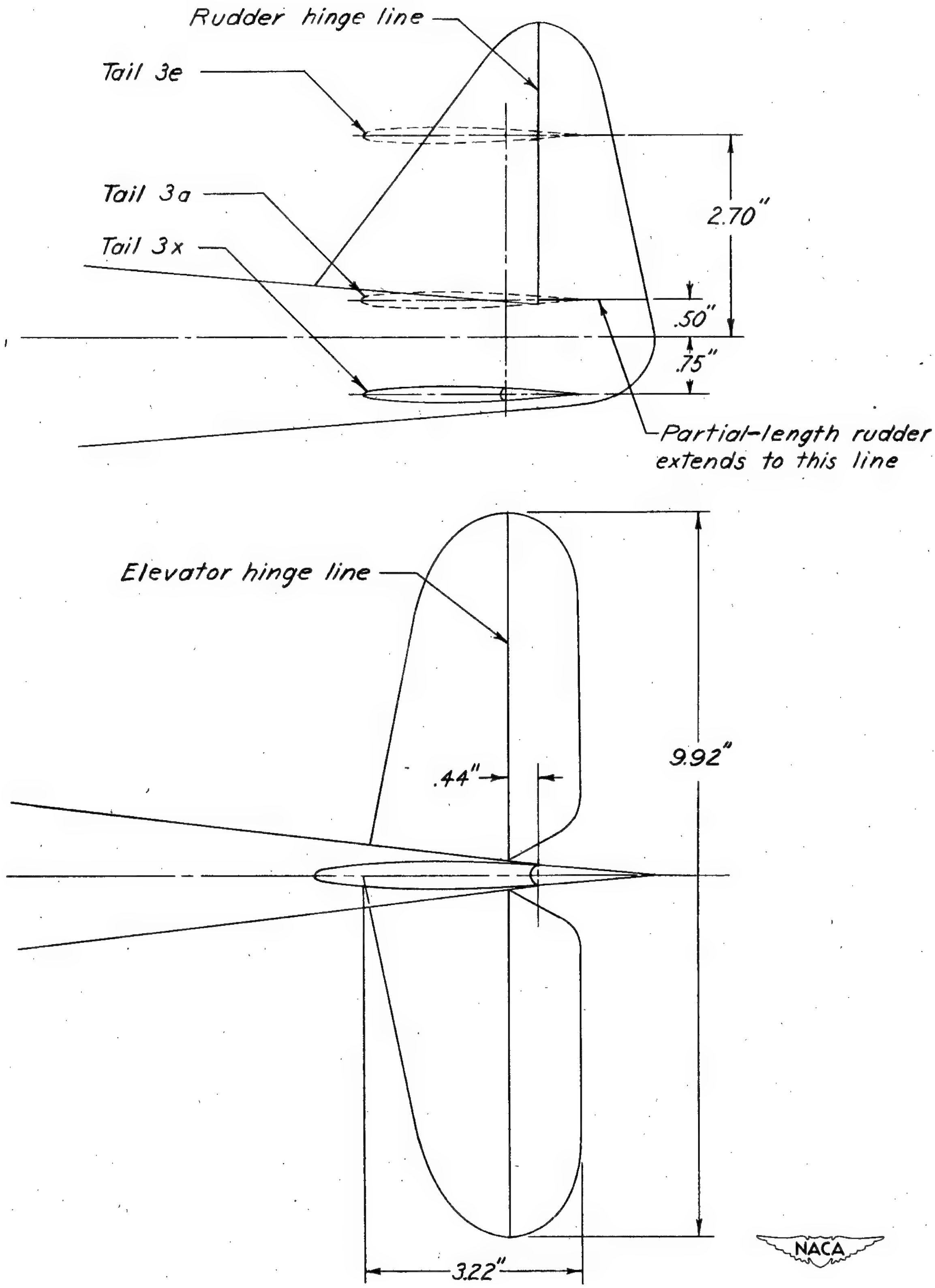


Figure 5.- The 3-series tails (partial-length rudder) tested on the model.

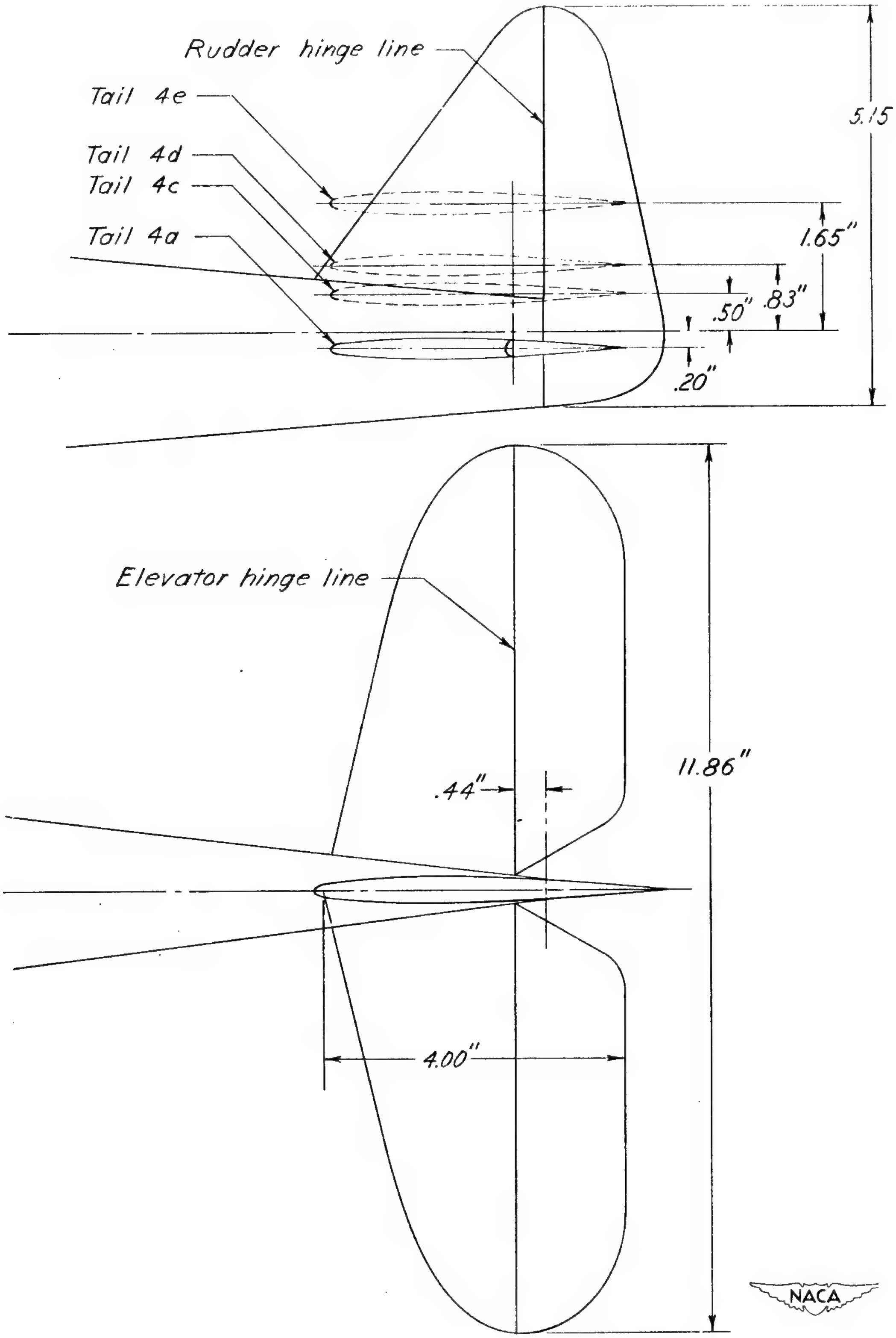


Figure 6.- The 4-series tails (large horizontal tail) tested on the model.

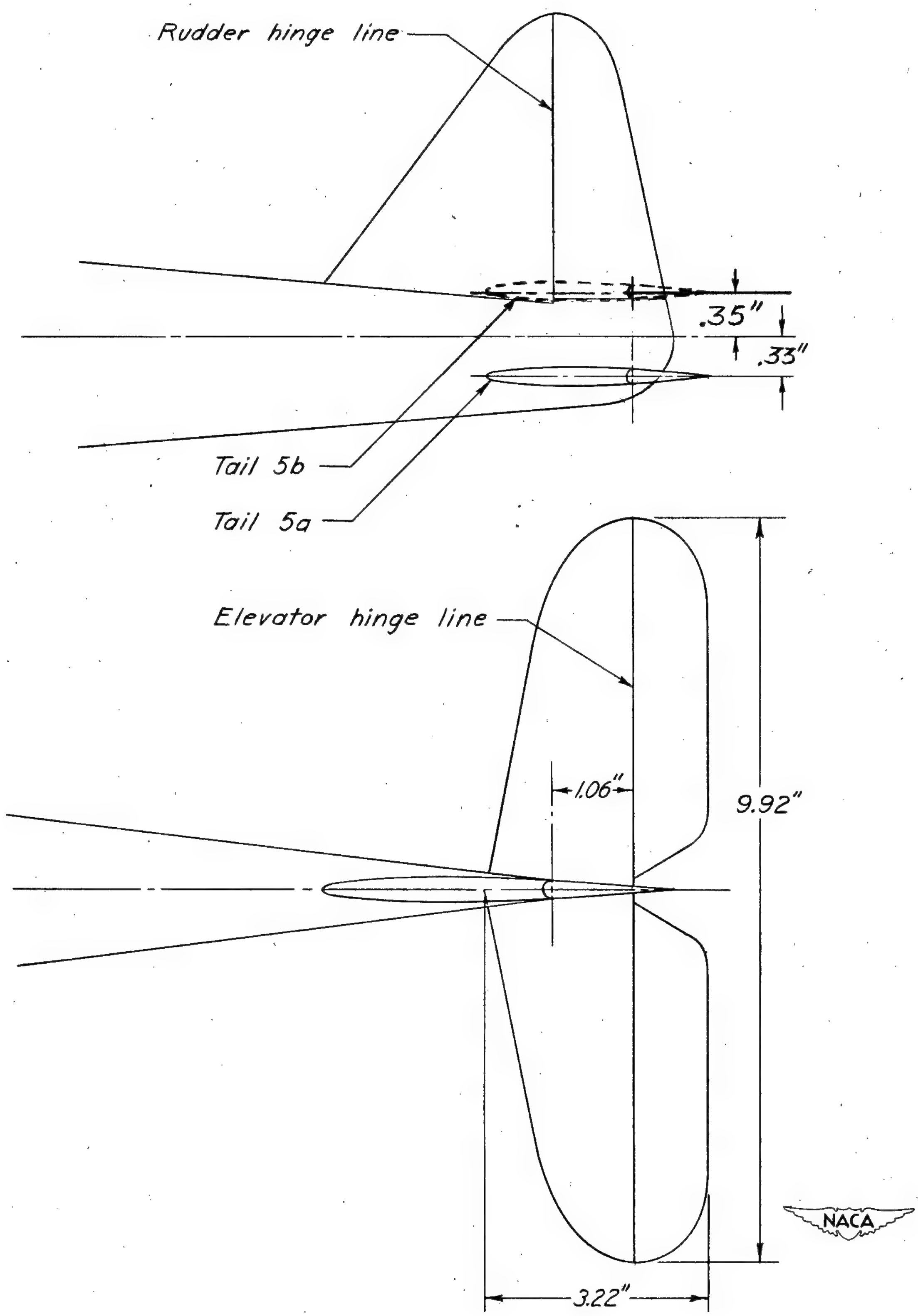
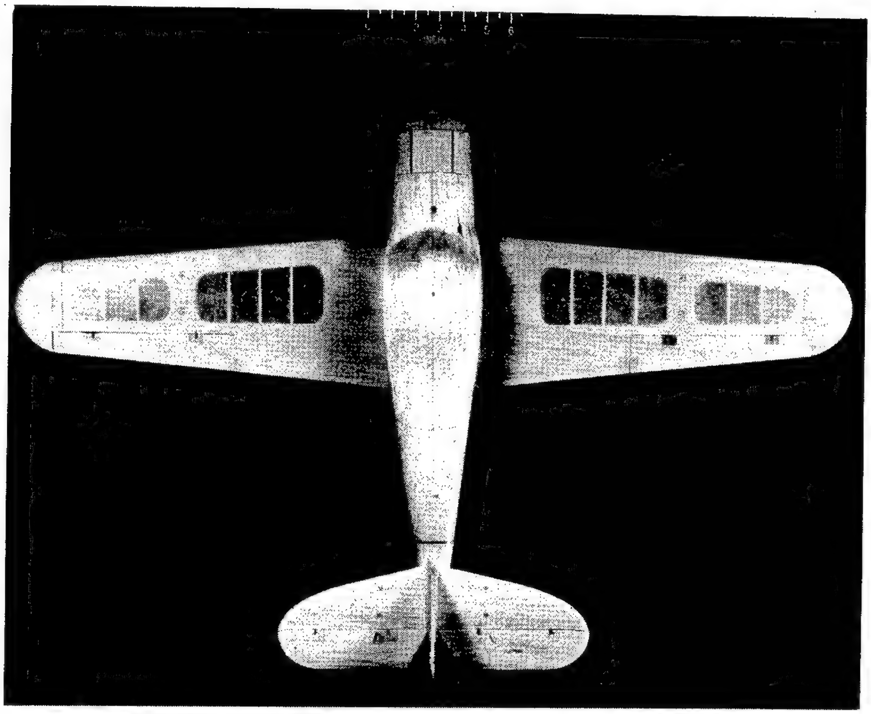


Figure 7.- The 5-series tails (partial-length rudder and horizontal tail moved rearward) tested on the model.



(a) Tapered wing; large horizontal tail.

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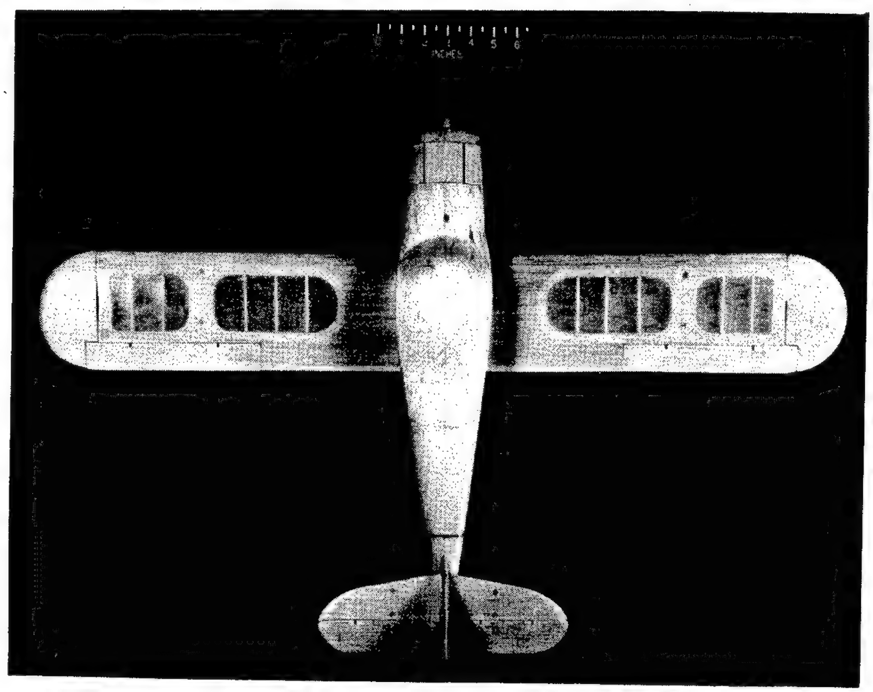

(b) Rectangular wing; normal horizontal tail.

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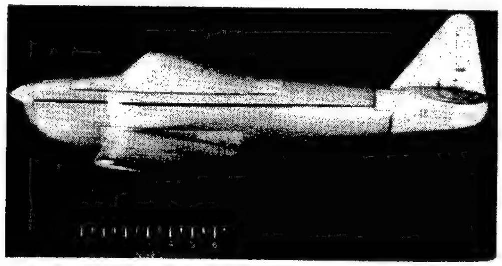
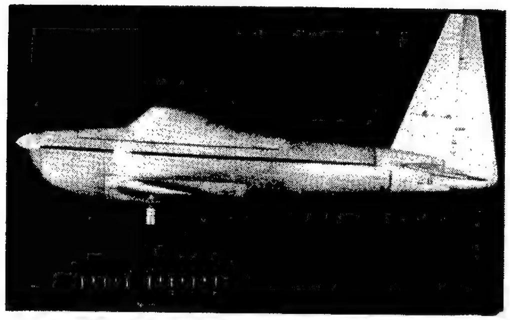
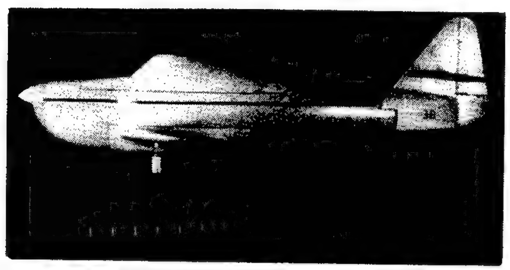
Figure 8.- Photograph of the wing and horizontal-tail plan forms tested on the model.



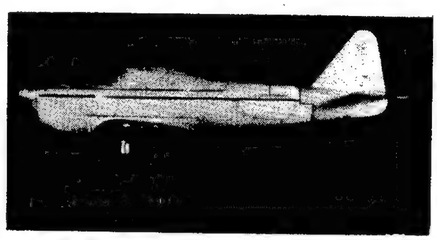
(a) Normal tail.



(b) Large vertical tail.



(c) Partial-length rudder.



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(d) Partial-length rudder; horizontal tail moved rearward.

Figure 9.- Photograph of the various vertical tails tested on the model.

Figure 10.- Photograph of the model spinning in the Langley 20-foot free-spinning tunnel.

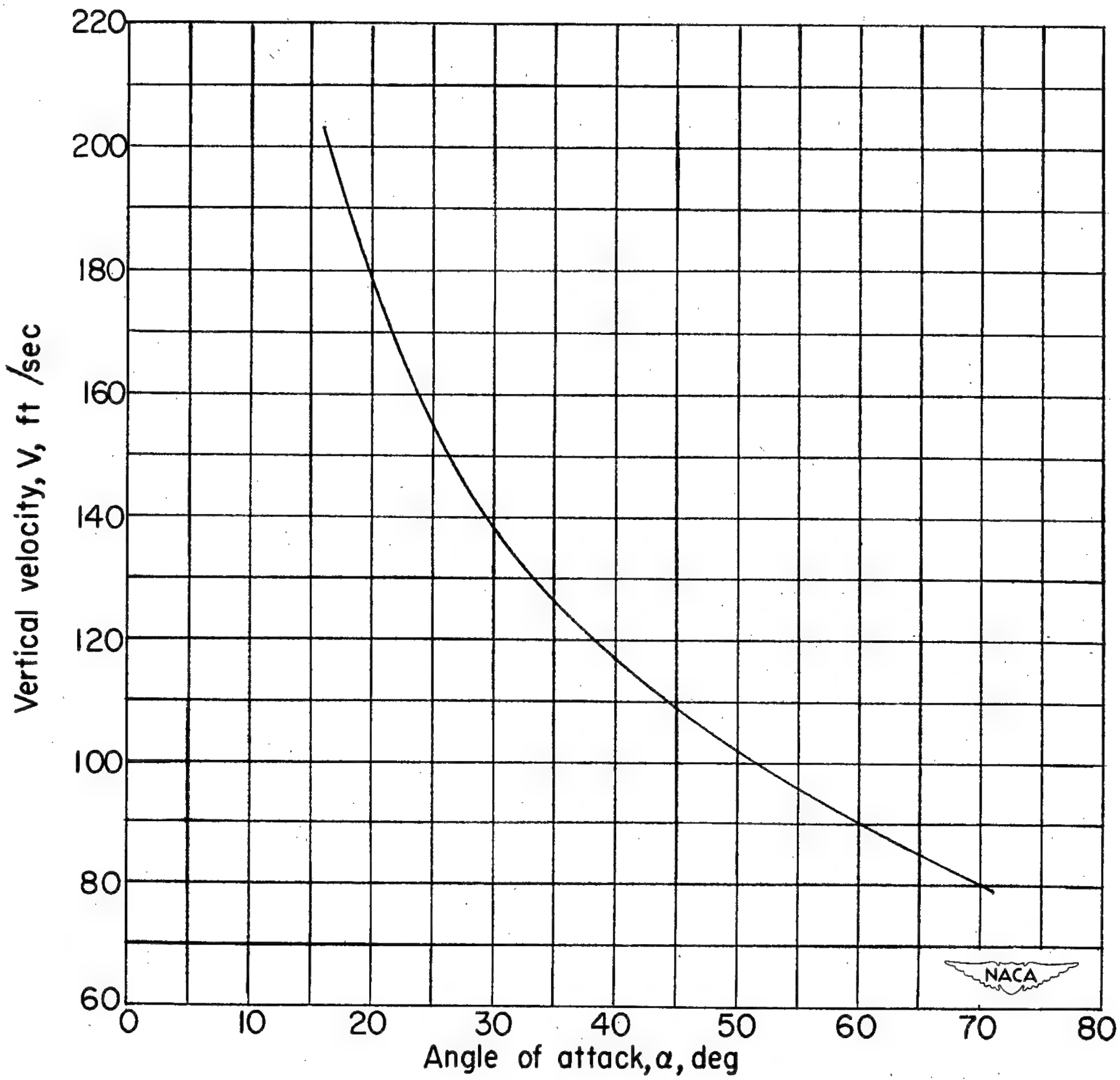
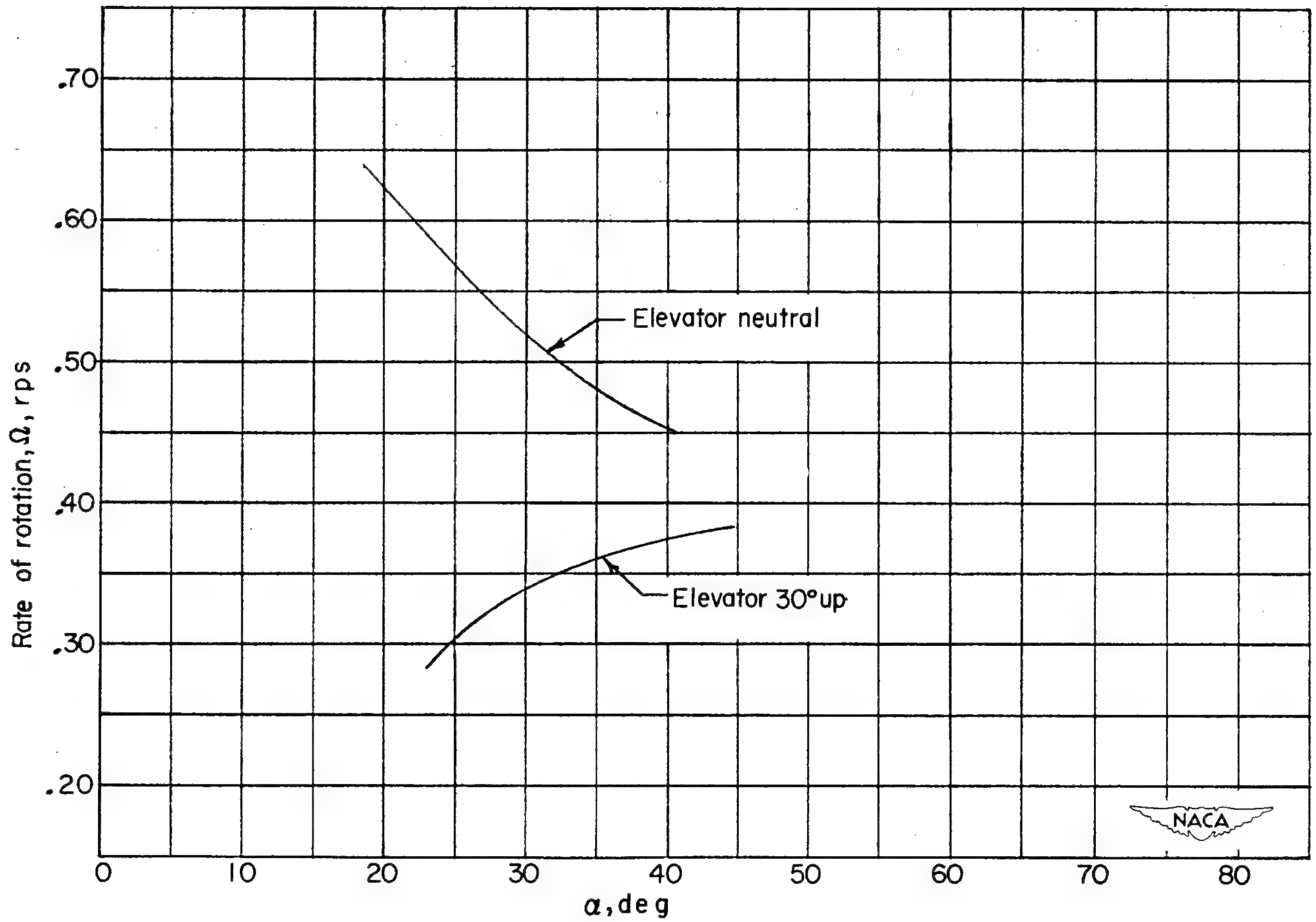
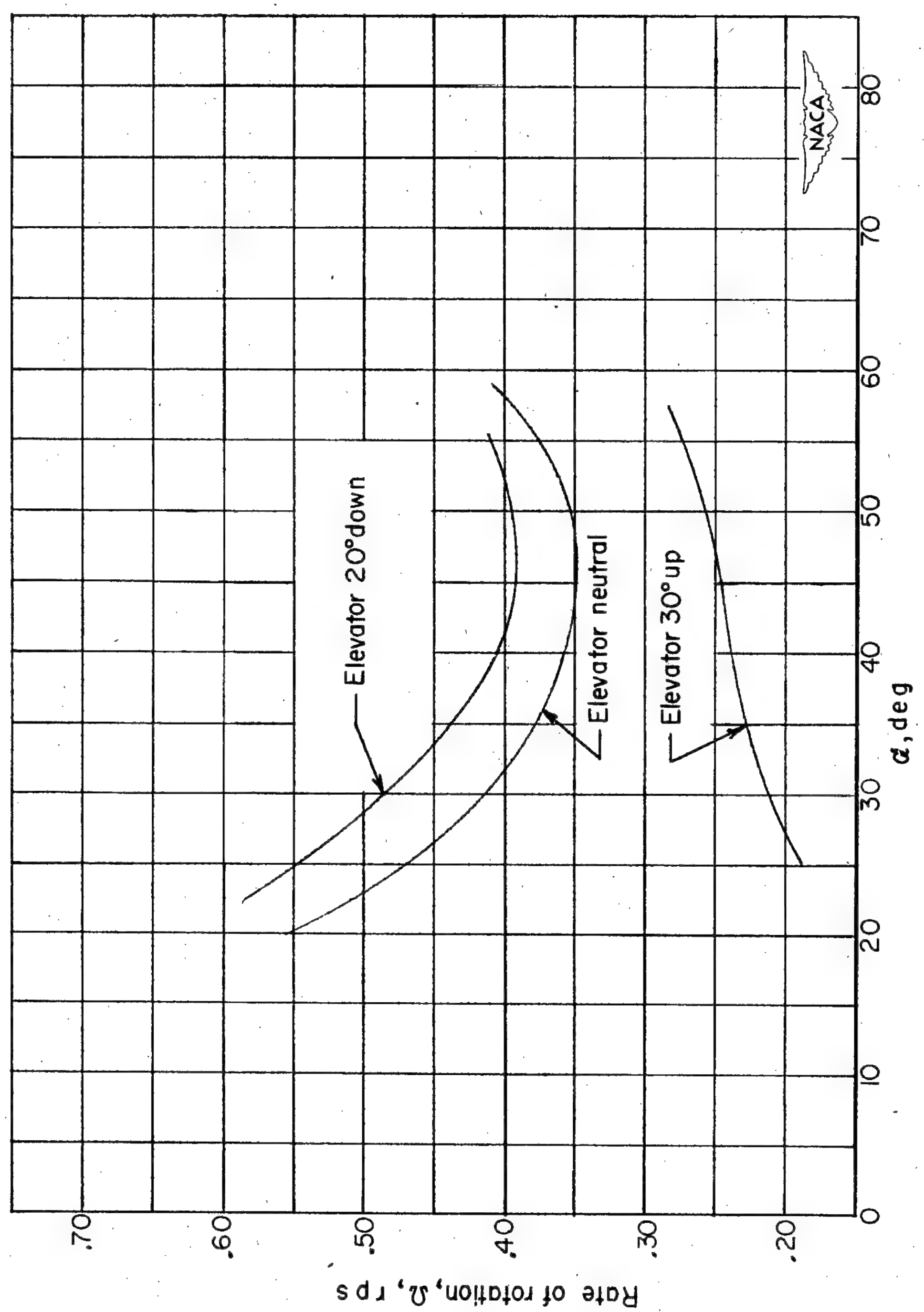


Figure 11.- Approximate variation of the full-scale vertical velocity with angle of attack during spins for an airplane similar to the model investigated.



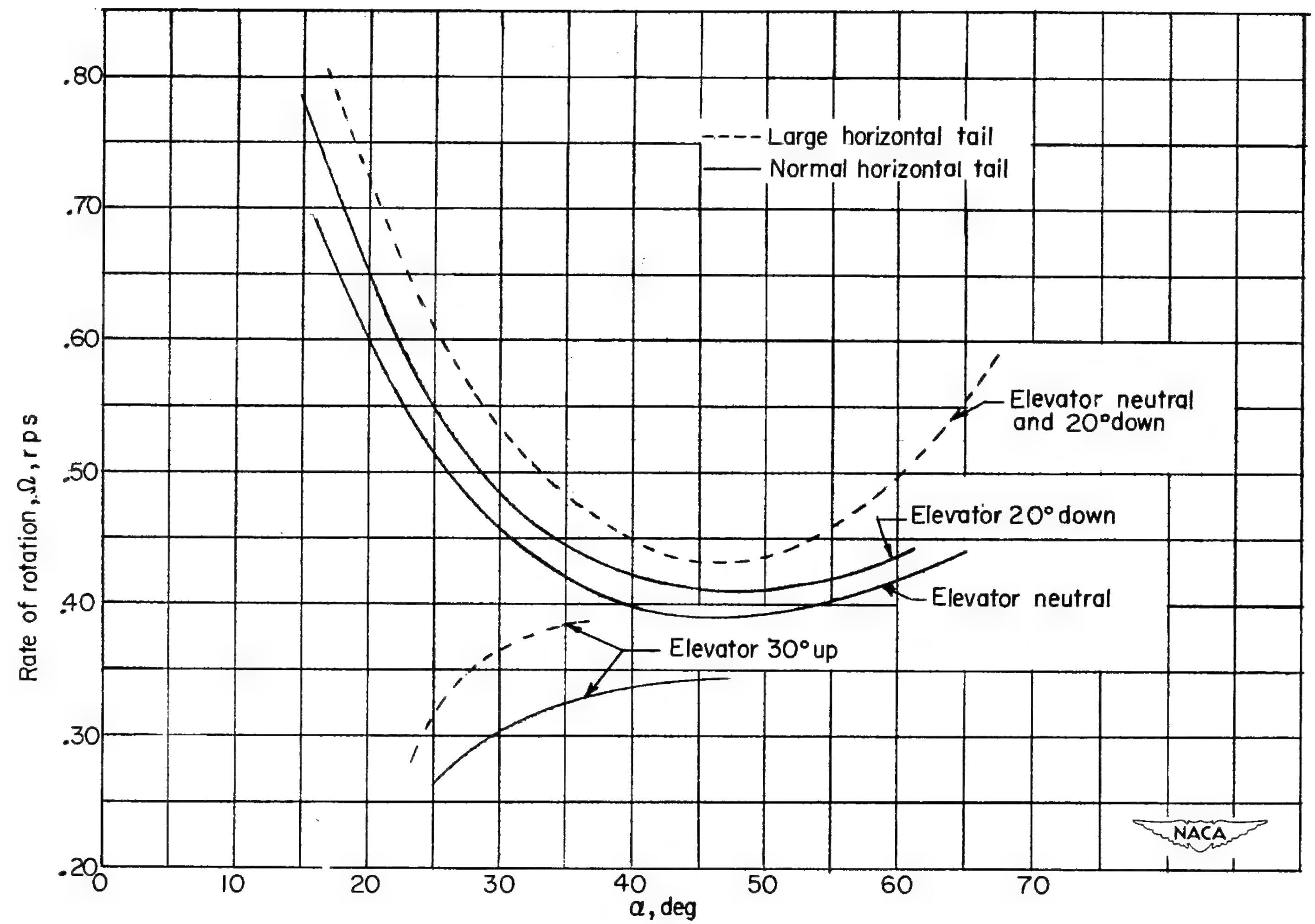
(a) Normal horizontal tail; loading 1; center of gravity at 25 percent $\bar{c}$.

Figure 12.- Approximate variation of the full-scale rate of rotation with angle of attack during spins for an airplane similar to the model investigated.



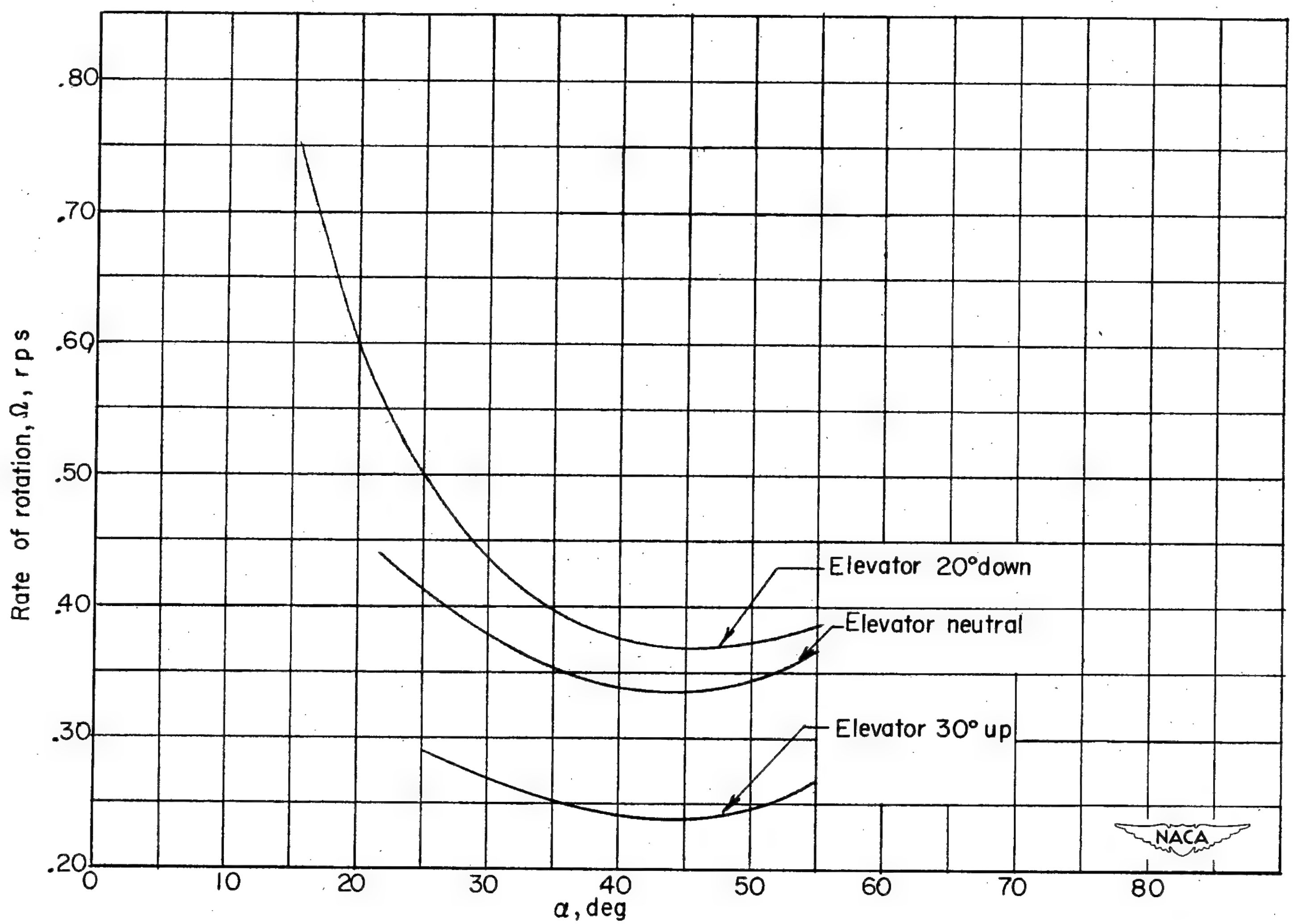
(b) Normal horizontal tail; loading 1'; center of gravity at 40 percent $\bar{c}$.

Figure 12.- Continued.



(c) Normal or large horizontal tail as indicated; loading 2; center of gravity at 25 percent $\bar{c}$.

Figure 12.- Continued.



(d) Normal horizontal tail; loading 2'; center of gravity at 40 percent $\bar{c}$.

Figure 12.- Concluded.

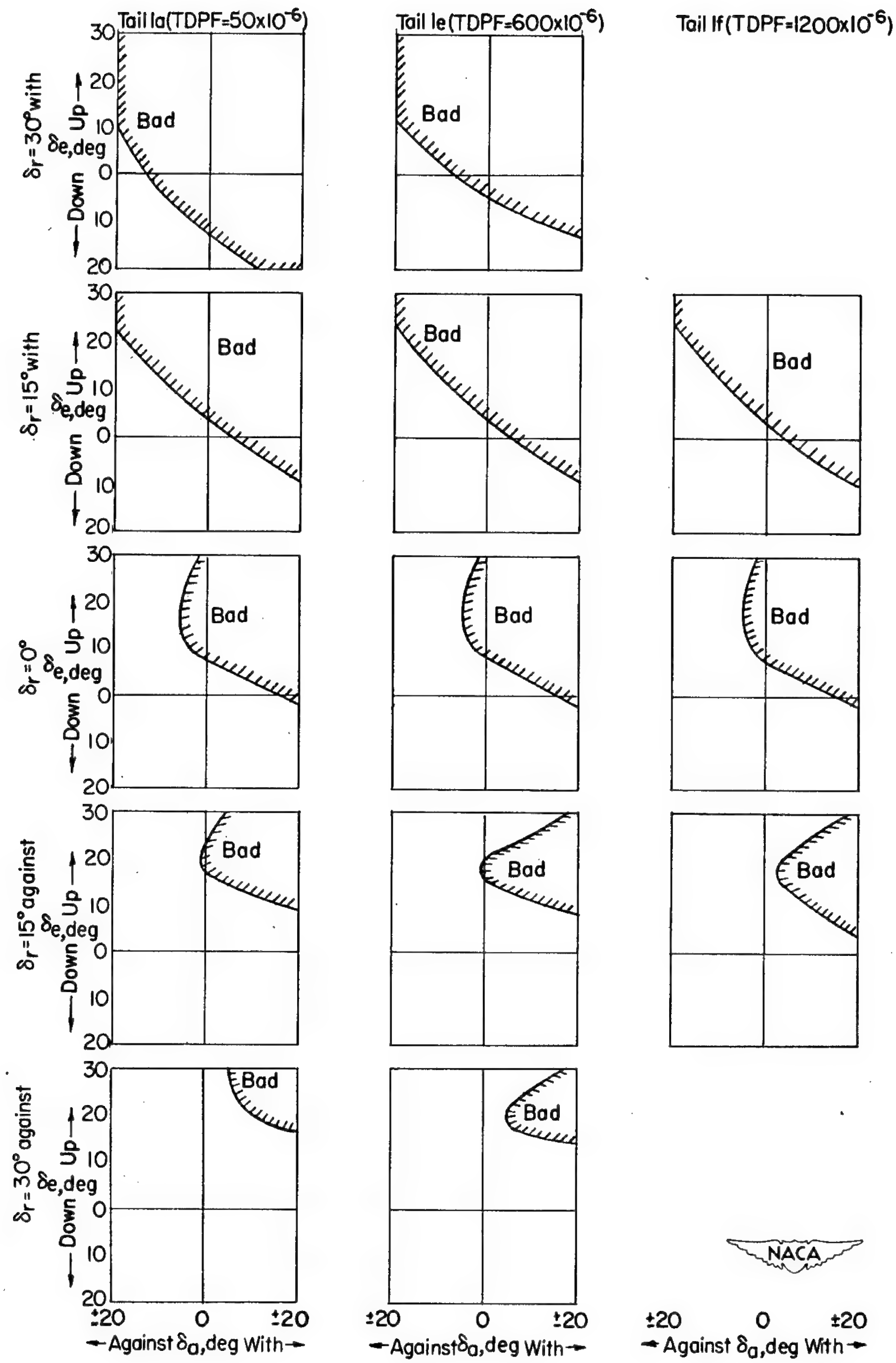


Figure 13.- Approximate elevator and aileron combinations that might be expected to lead to satisfactory or unsatisfactory recoveries after control release for various rudder floating positions. Loading 1; center of gravity at 25 percent $\bar{c}$.

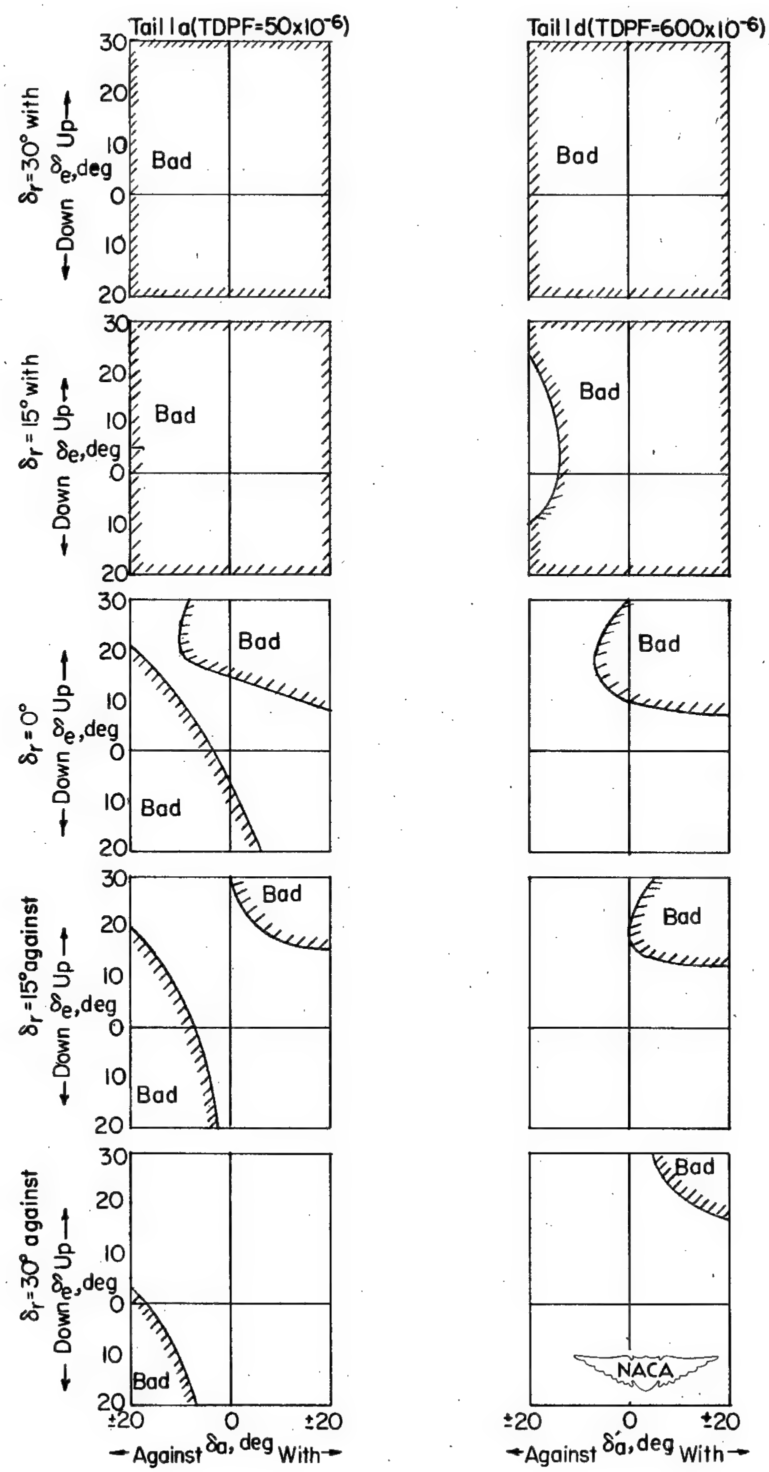


Figure 14.- Approximate elevator and aileron combinations that might be expected to lead to satisfactory or unsatisfactory recoveries after control release for various rudder floating positions. Loading 2; center of gravity at 25 percent $\bar{c}$.

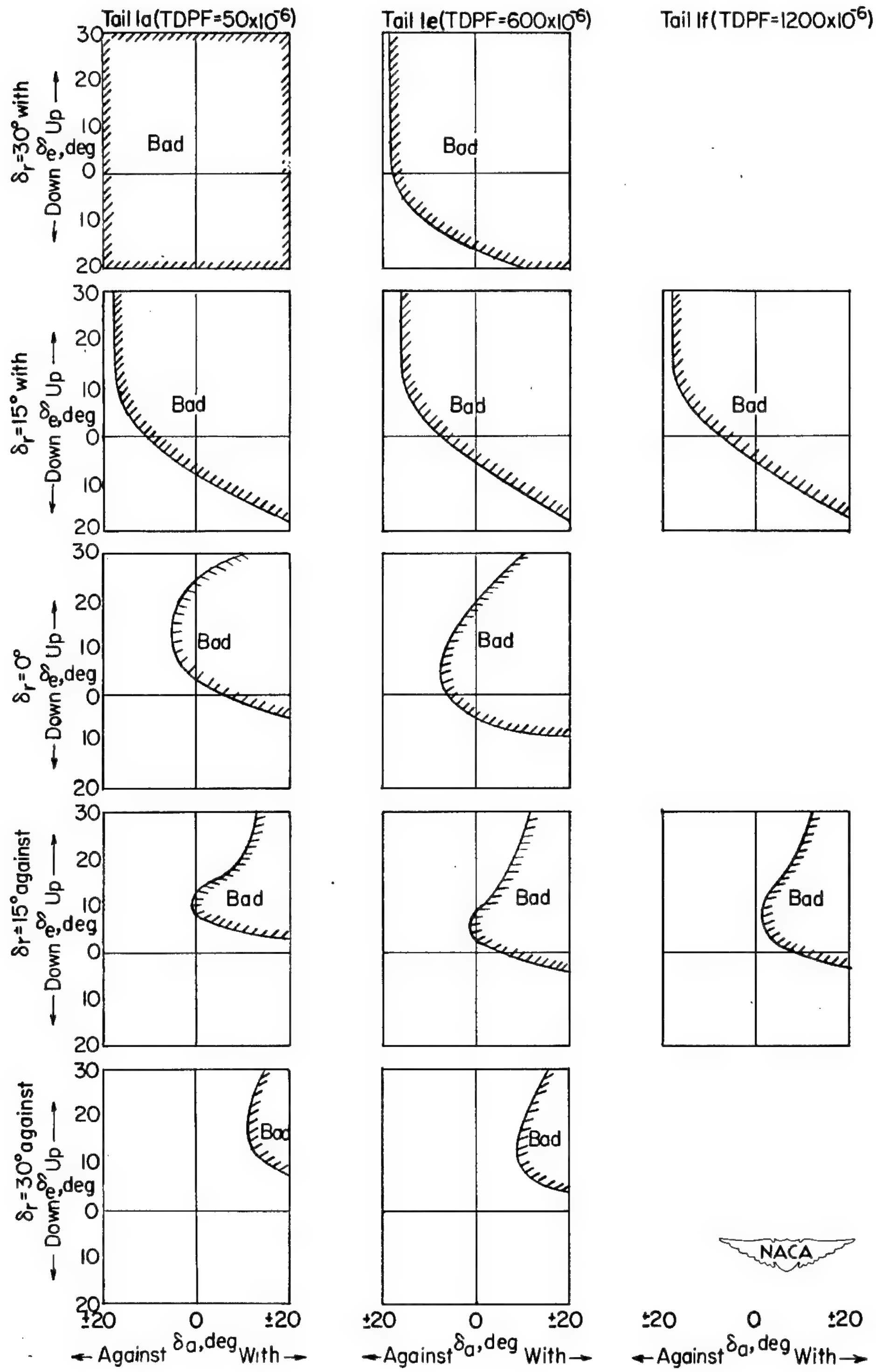


Figure 15.- Approximate elevator and aileron combinations that might be expected to lead to satisfactory or unsatisfactory recoveries after control release for various rudder floating positions. Loading 1'; center of gravity at 40 percent $\bar{c}$.

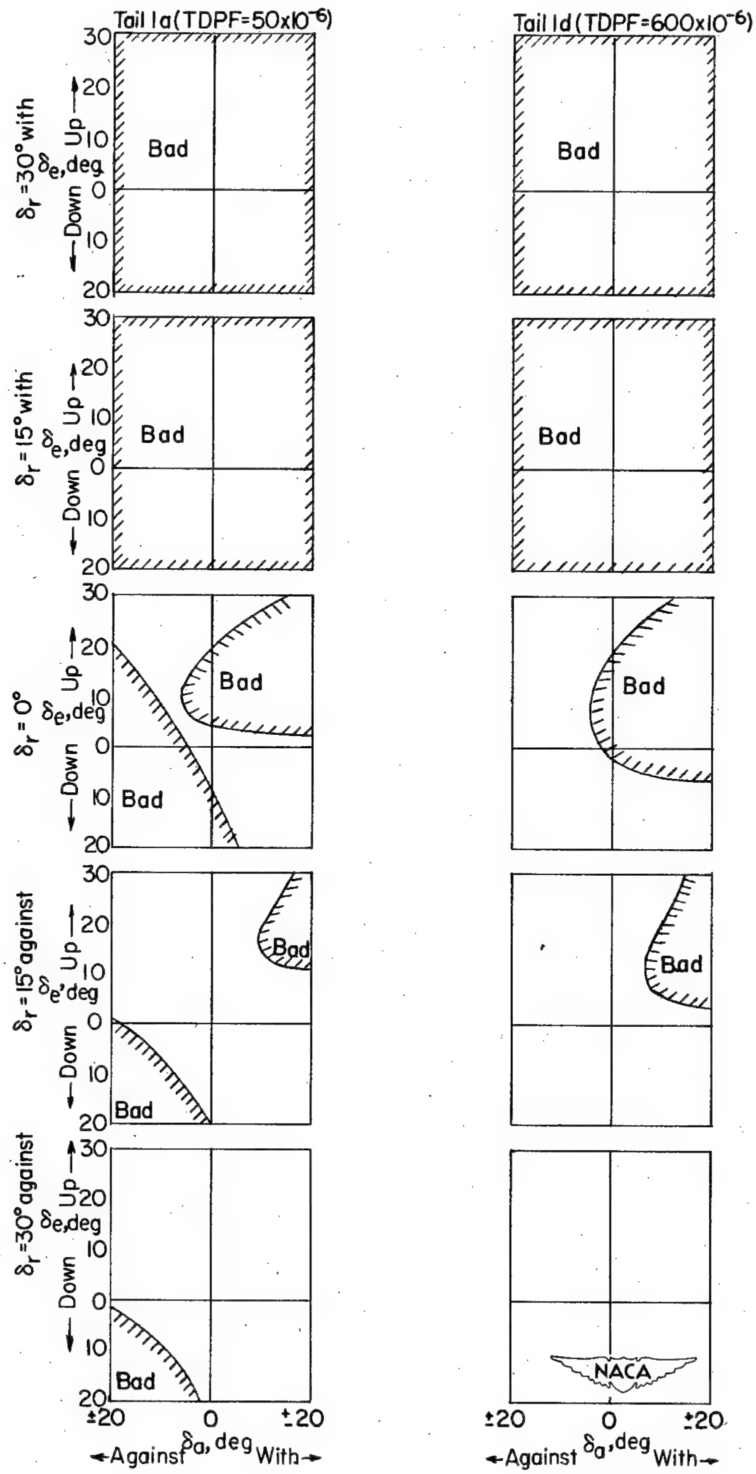


Figure 16.- Approximate elevator and aileron combinations that might be expected to lead to satisfactory or unsatisfactory recoveries after control release for various rudder floating positions. Loading 2'; center of gravity at 40 percent $\bar{c}$.

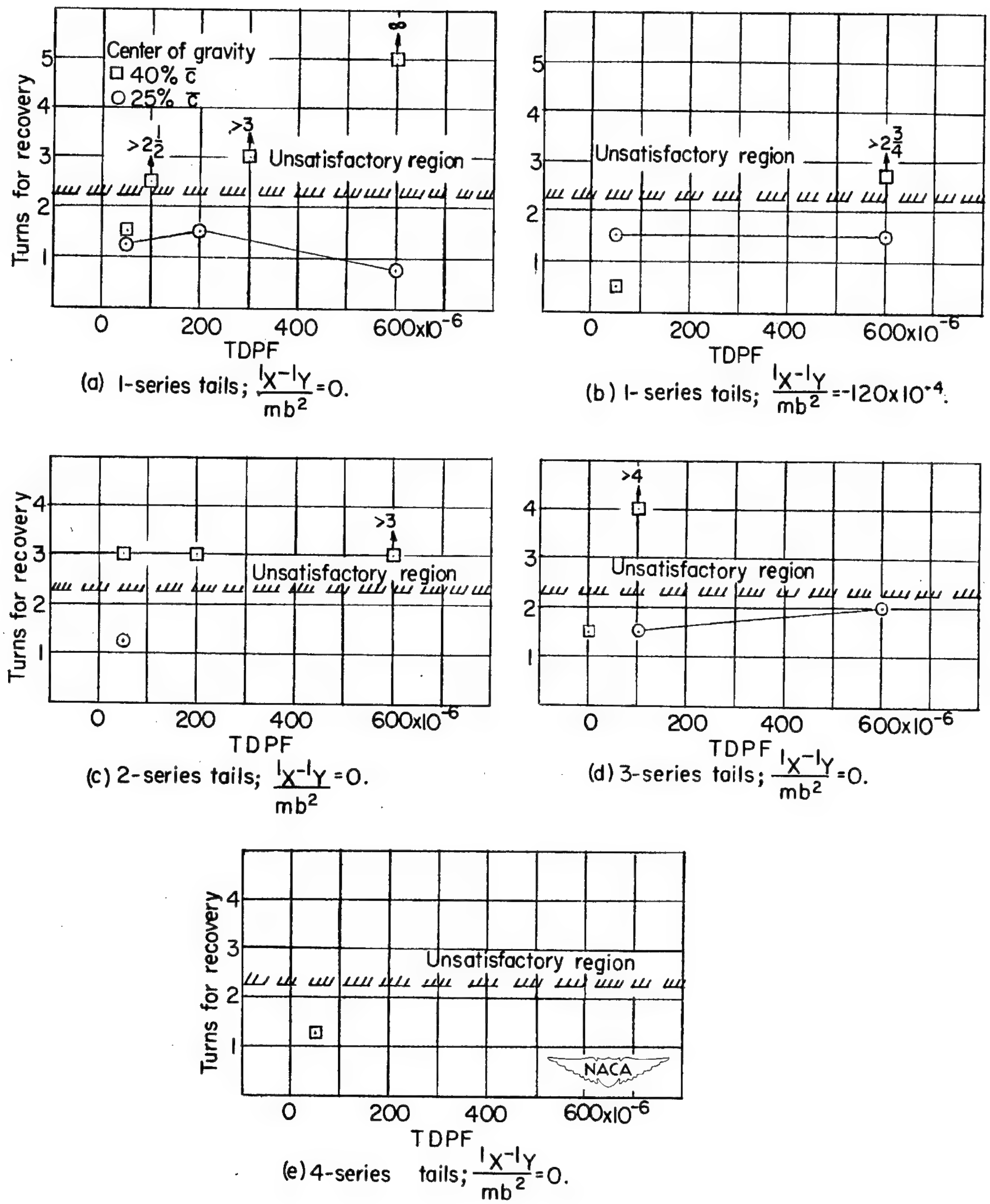


Figure 17.- Effect of tail-damping power factor on turns required for recovery by simultaneous rudder and elevator neutralization. (See table V.)

Abstract

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NACA TN 2352

Spinning 1.8.3
L

Spin-Tunnel Investigation of the Effects of Mass and Dimensional Variations on the Spinning Characteristics of a Low-Wing Single-Vertical-Tail Model Typical of Personal-Owner Airplanes.

By Walter J. Klinar and Jack H. Wilson

NACA TN 2352

May 1951

(Abstract on Reverse Side)

Control 1.8.2
L

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Tail-Wing-Fuselage
Combinations - Airplanes 1.7.1.1.3
L

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Safety 7.1
L

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Mass and Gyroscopic Problems 1.8.6 L

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Piloting Techniques 7.7 L

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